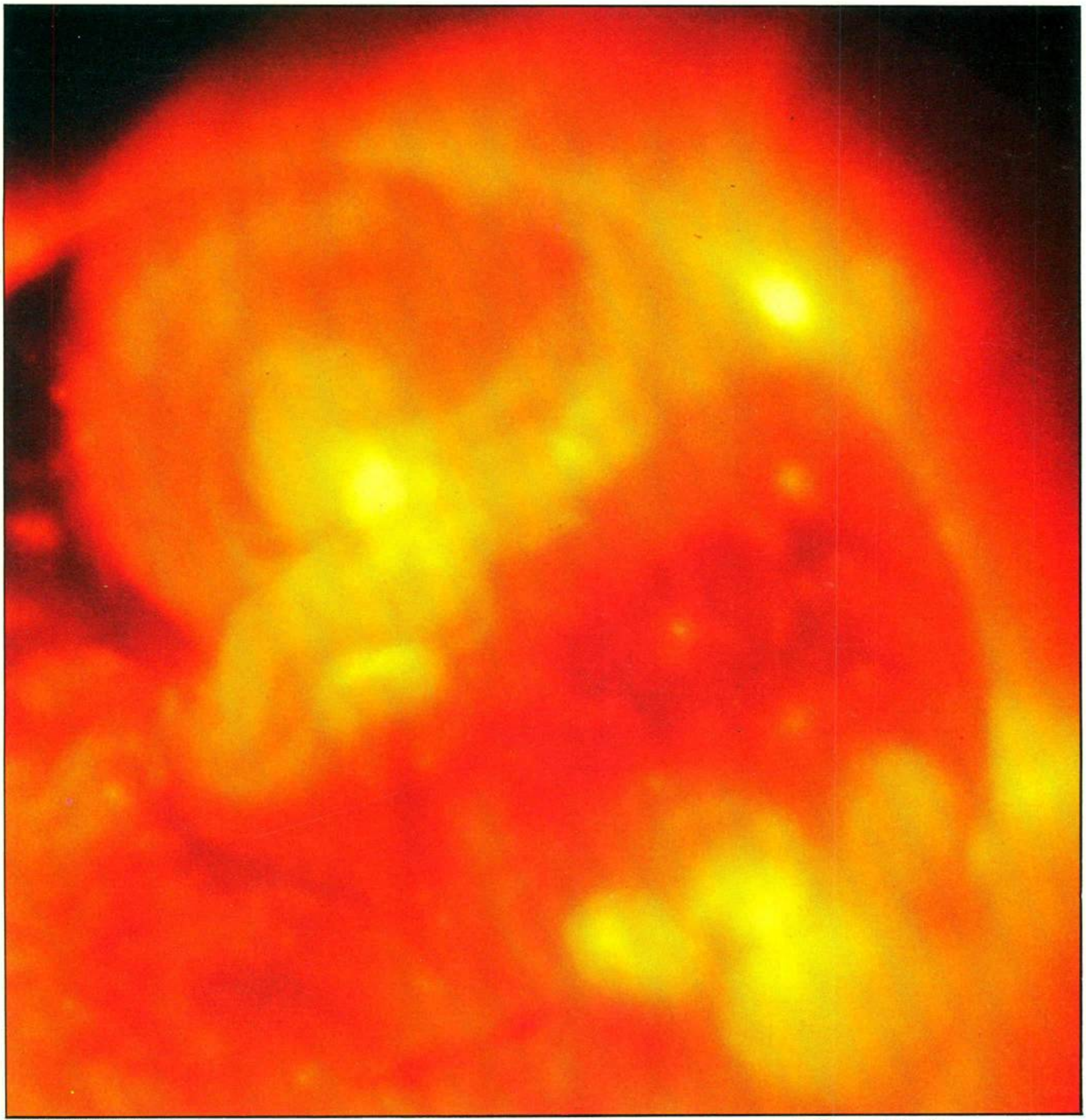
# ASTRONOMY

May 1980
$2

## Colors of Mars

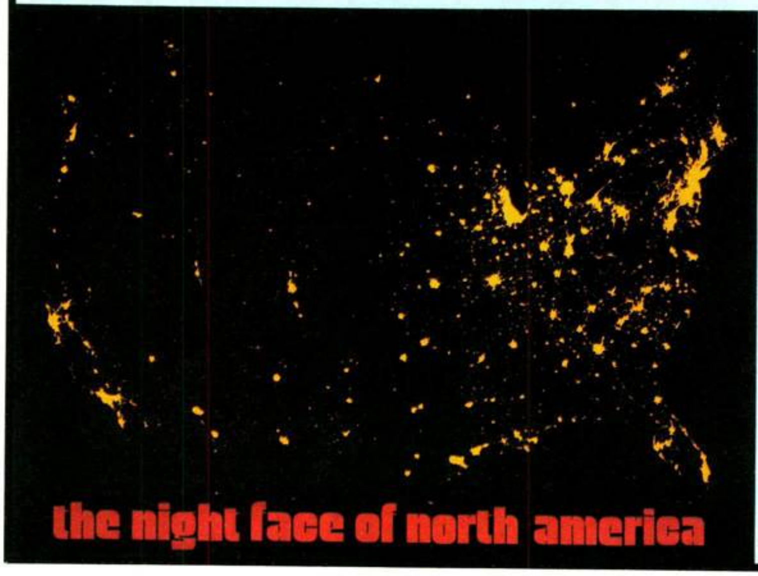
## The Afro-Indian Shadow Connection

## Asteroids: The Flying Mountains



## Sunspots ● The X-Ray Sun

## The Night Face of North America



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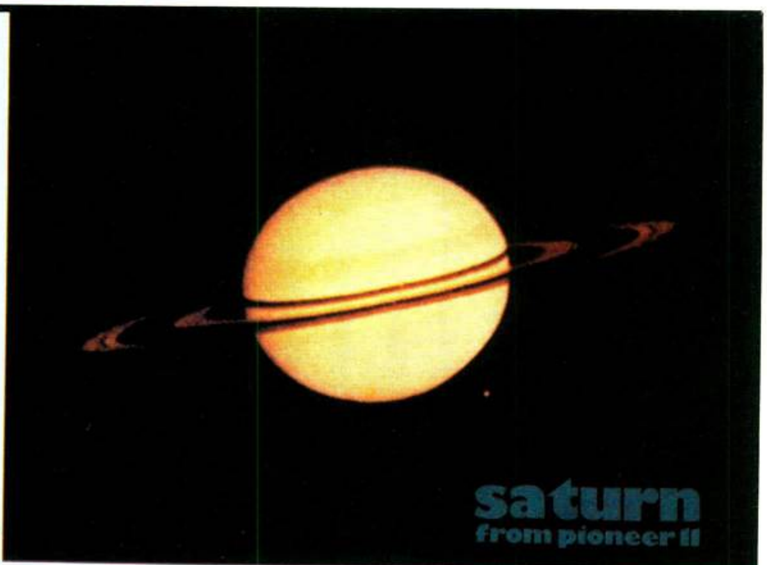
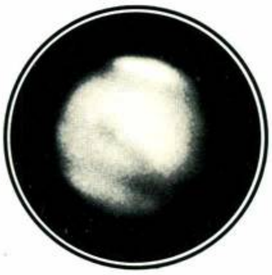


# CELESTIAL EXPECTATIONS in the 80's

**THE SPECTACULAR HALLEY'S COMET** ... Plans are under way already by virtually every astronomer to take advantage of the return of Halley's Comet in 1986. Because of city lighting and an unfavorable positioning of the comet relative to earth, Halley's Comet is not expected to be as well seen as the 1910 apparition. Nonetheless, for many astronomers it will be the only appearance of this famous interloper.

**THE GIANT PLANET JUPITER** ... Every year of the 80's giant Jupiter will provide observers and astrophotographers with a spectacle of events; the swirling cloud belts present ever-changing faces which the serious amateur studies in hopes of better understanding the circulations of this colossal gaseous globe. Astronomers are eagerly awaiting the reappearance of the now-vague Great Red Spot of Jupiter seen for over 300 years, but disappearing in 1975. With it's oppositions appearing in early Spring and Summer during the 1980's, Jupiter will be perhaps the best-watched of all the planets.



**MARS AT OPPOSITION IN 1988** ... This will be the most favorable opposition of the planet Mars since the memorable apparition in 1971. Observers world-wide will be monitoring the planet Mars for subtle changes in the south polar-cap as Mars approaches it's nearest point to the earth. As the large cap melts, a mysterious wave of darkening sets in on the Maria of the Martian plains, a phenomenon observed for centuries by astronomers, yet still not understood.

**SATURNS RINGS** ... Will slowly open through the early part of the eighties, presenting the northern face and the northern hemisphere of the planet. Even small instruments can show the ring system of Saturn remarkably well, as well as many fine belts traversing the planets face.

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| | MARS | JUPITER | SATURN | COMETS |
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| VISUAL OBSERVING: | | | | |
| Scope Requirements | 6″ or larger | 2.4″ or larger | 2.4″ or larger | RFT or binoculars |
| Notable Features | Polar Caps | Great Red Spot | Ring Divisions | Nucleus, Tail |
| Magnification | 300-400x | 250x | 250-400x | under 100x |
| Eyepiece Type | Ortho | Ortho | Ortho | Erfle or Plossl |
| Filter Type | W-21 or W-25 | W-80A or W-58 | W-12 | none |
| PHOTOGRAPHY: | | | | |
| Optical Needs | 6″ or Larger | 2.4″ or larger | 6″ or larger | Piggyback camera or Schmidt Camera |
| Color Film | Ekta. 400 | Ekta. 400 | Ekta. 400 | Ekta. 400 |
| B & W Film | SO-115 | SO-115 | SO-115 | 103aE |
| f/ratio | f/80 | f/80 | f/80 | lowest possible |
| Exp. time (color) | 1 sec. | ½ sec. | 3 sec. | 5-10 minutes |
| (B&W) | 4 sec. | 1 sec. | 8 sec. | 5-10 minutes |

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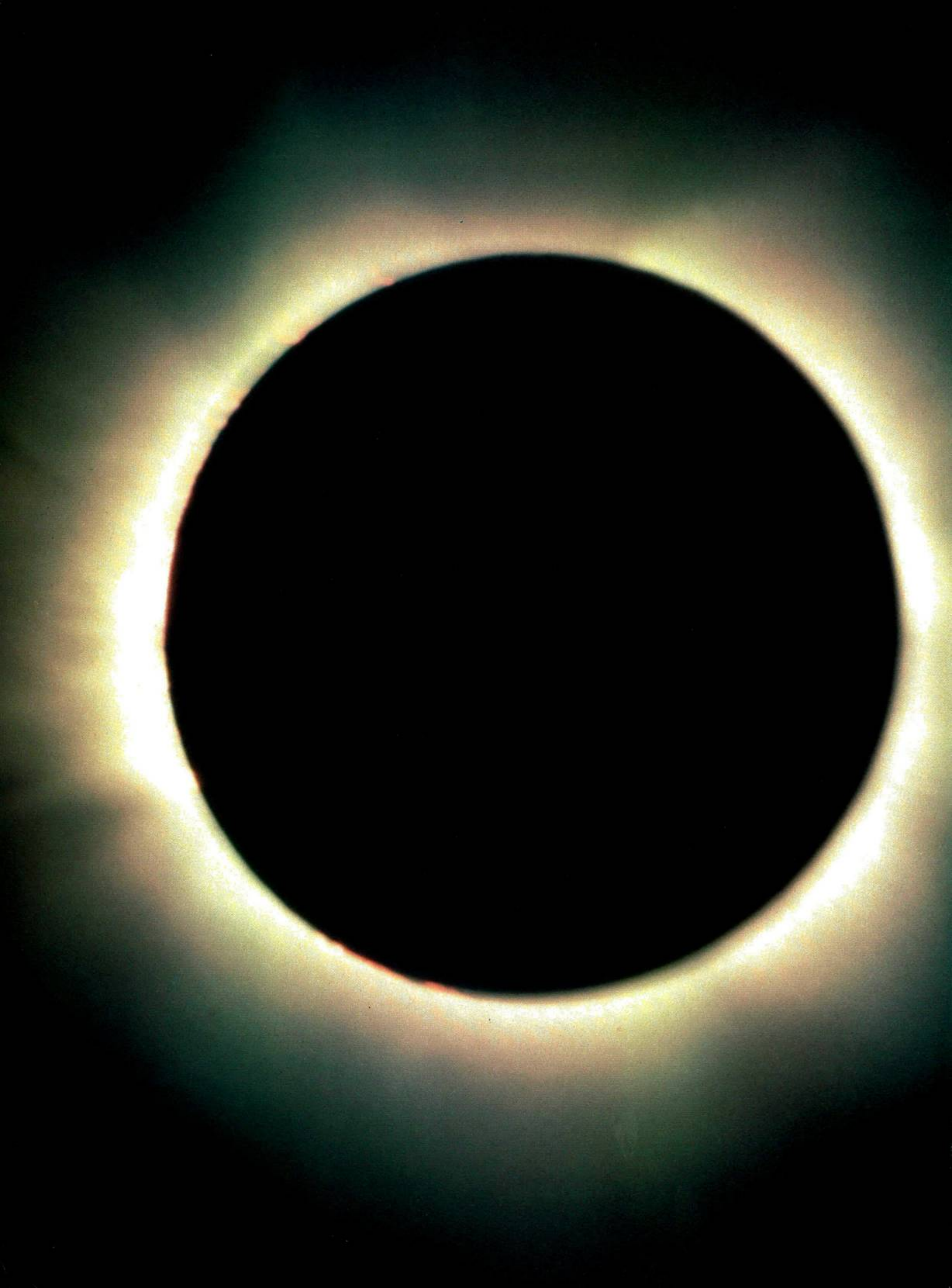

# ASTRONOMY

Vol. 8, No. 5
May 1980

The World's Most Beautiful Astronomy Magazine • Established by Stephen A. Walther

6 **The Colors of Mars**
by Edwin Strickland

16 **Asteroids: The Flying Mountains**
by Joel Davis

Forum 24 **Have You Heard the Stars Tonite? An Interview with Ken Atkins**

Eye on the Sky 30 **Venus: Beacon in the West**

Eclipse Special 38 **The Afro-Indian Shadow Connection**
by Ben Mayer

Photography in Astronomy 47 **An Album of Galaxies**
by Thomas L. Dessert

In Focus 50

Behind the Scenes 51

Gazer's Gazette 52 **You're Looking in the Wrong End, Charlie!**

Astronomy Reviews 56

AstroNews 58

Stellar Frontiers 66 **Sunspots**
by Philip A. Stahl

AstroMart 72

Through the Eyepiece 78 **Close-Up on Virgo**

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Cover: The familiar sunspots, the esoteric "active regions," and beautiful solar corona are all tied to the Sun's magnetic field. This X-ray photograph shows the corona, its plasma twisted by the solar magnetic field, enveloping the Sun. Sunspots, the subject of Stellar Frontiers, lie beneath the X-ray-bright features called "active regions." American Science and Engineering photograph courtesy of John M. Davis. This page: Seen from Africa on February 16, the solar corona glowed with soft radiance. See this month's Eclipse Special on page 38. Photograph by Steve Edberg.

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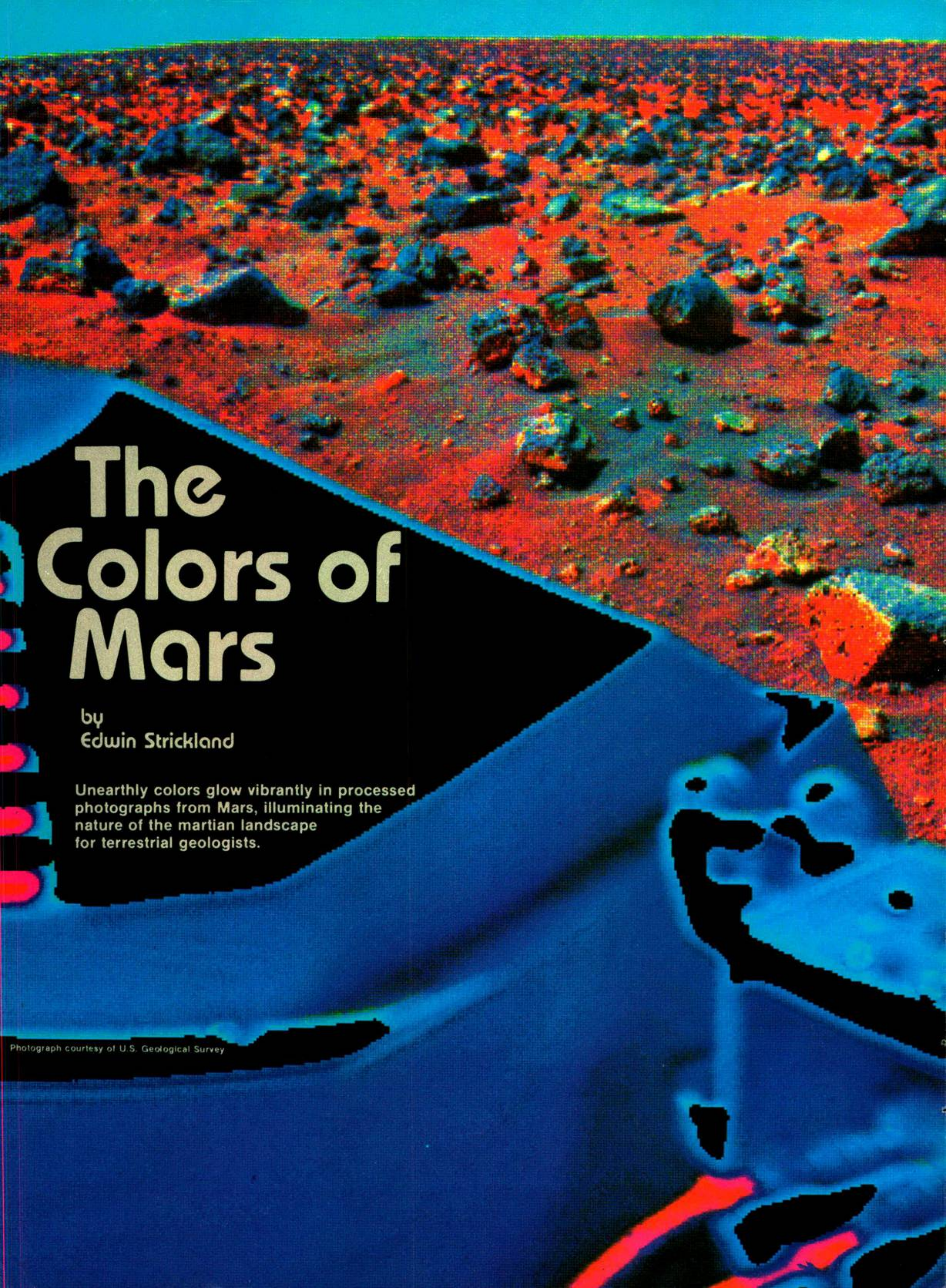
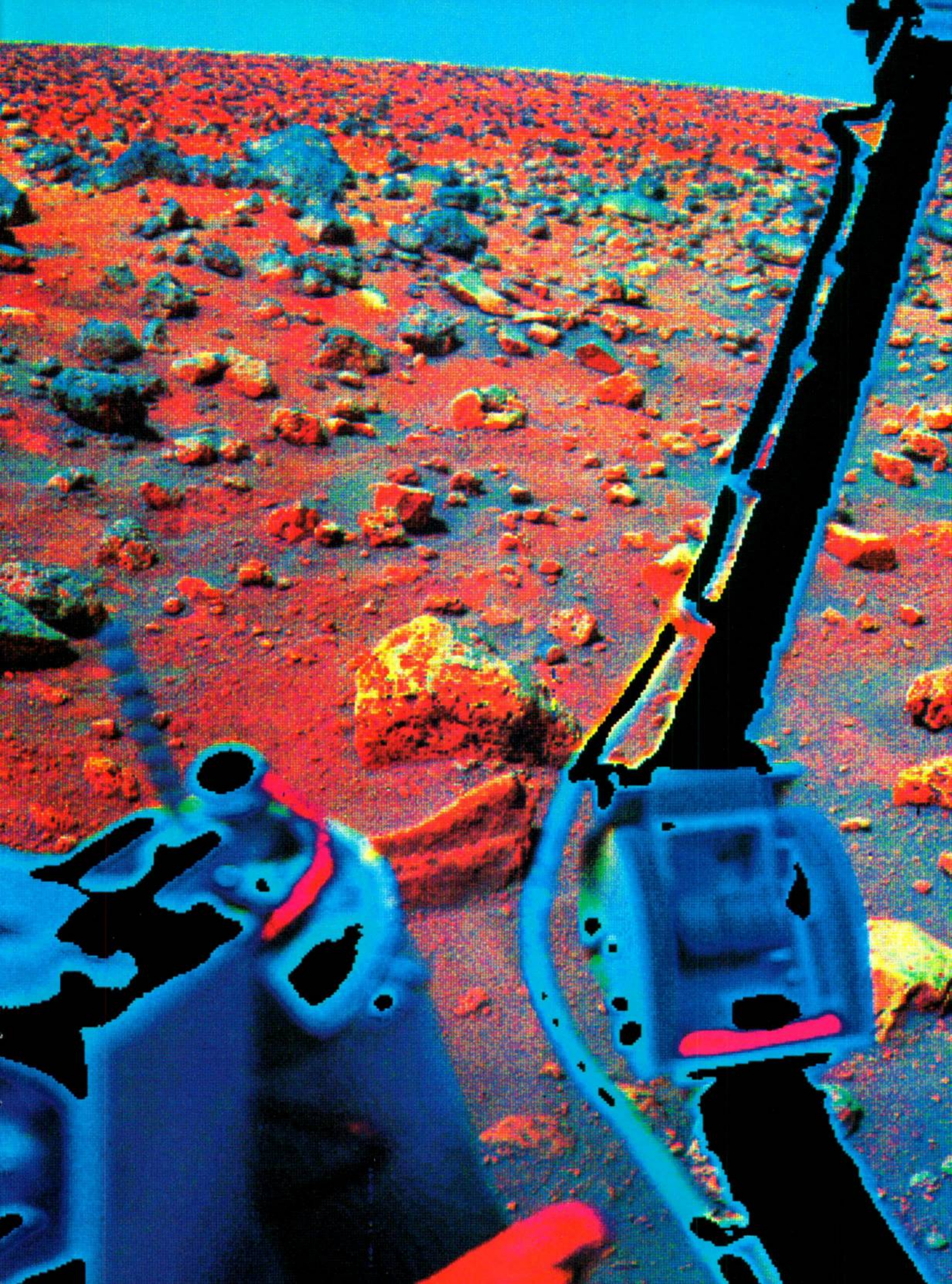


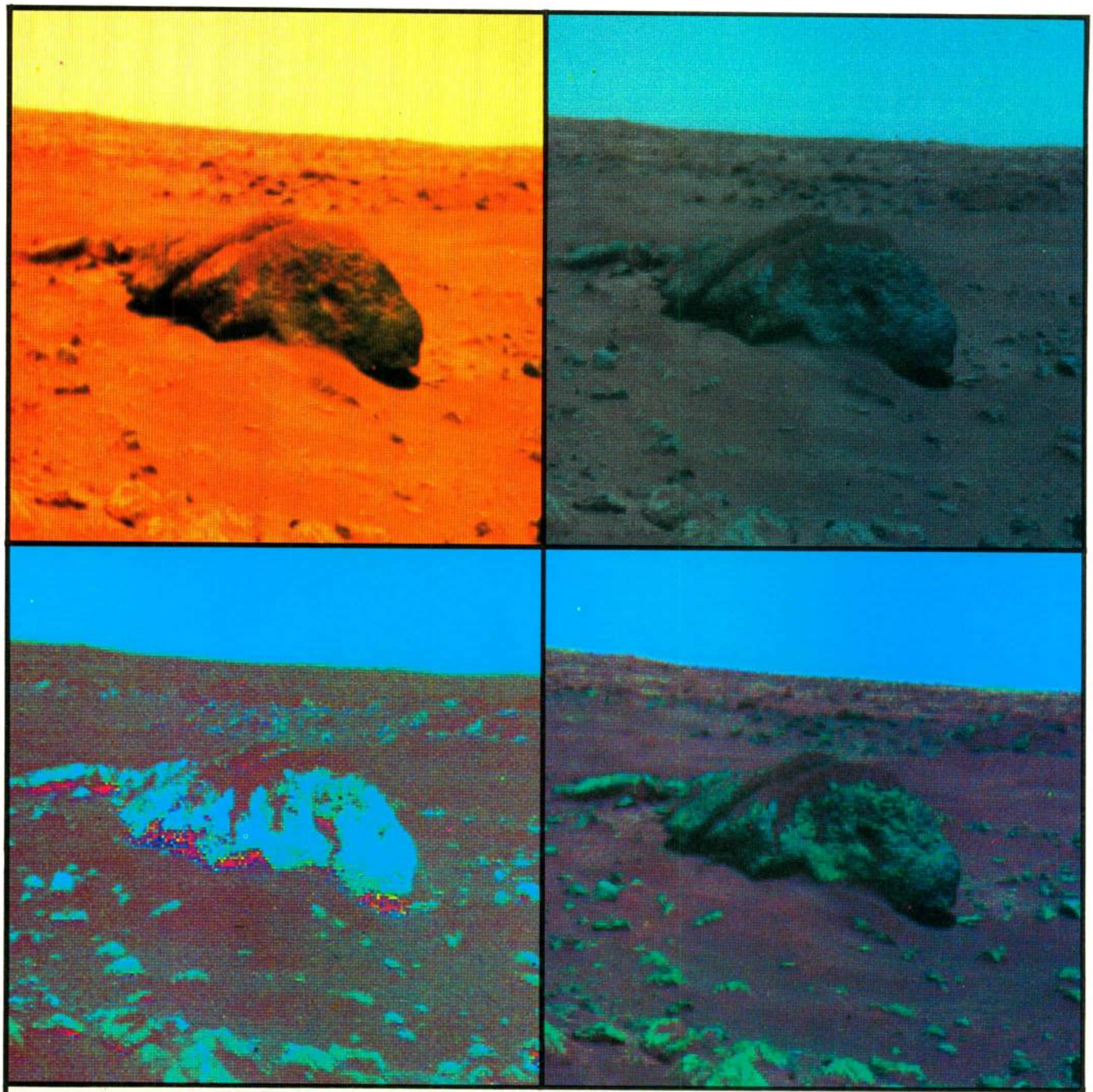
# The Colors of Mars

by
Edwin Strickland

Unearthly colors glow vibrantly in processed photographs from Mars, illuminating the nature of the martian landscape for terrestrial geologists.

Photograph courtesy of U.S. Geological Survey





# Coloring Mars with a Computer

Highly-enhanced color pictures of the martian landscape are easy to make with a computer. At upper left, the famous rock known as "Big Joe" is seen in natural, unprocessed color. The first step in the enhancement process averages all the colors in each picture, resulting in a neutral gray balance (upper right). Next, the color information is separated from the brightness information in each one of the three color images. The picture at lower left shows the "blueness" image. Then the computer "stretches" the range of numbers representing each color, resulting in an unnatural enhancement. Finally, the brightness information is recombined with the three enhanced color images, and the three assembled into a final picture (lower right). Such pictures enable scientists to tell us a great deal about the various geological components in the scene. (First picture courtesy of NASA/JPL; others U.S. Geological Survey.)

A small, impossibly cobalt blue Sun stands near the zenith. Under the dark blue sky, on the rolling, rocky plain, stands a three-legged spacecraft, the same cobalt blue as the Sun. Loose rocks are strewn across the plain. Some are dark blue, others are bright green, and many are a mix of the two colors. On a small outcrop of bedrock beside the spacecraft, the edges and tips of the rocks are dark blue, while the faces are green. A thin coating of bright red dust covers most of the powdery soil that lies between the rocks. In places, the thin wind has blown away the red dust; there, dark blue and green-blue soils appear. Beside the spacecraft, under one of its descent rockets, is a uniquely colored patch of crustlike, bright orange-red soil. Five meters away, beyond the green and blue bedrock, rests a large blue boulder capped with dark red dust. Small shadows are visible under the spacecraft and rocks, where the noontime Sun cannot reach. Despite the blue color of the sky, they appear to be lit by a reddish glow of scattered light. In this strange scene, the only motions are the slow rotation of a camera shroud on the spacecraft and the imperceptible westward transit of the Sun toward the western horizon.

This alien scene is not an astronomer's hallucination, nor the set for another cheap space opera. Instead, it is the familiar reddish landscape of Mars, portrayed in computer-enhanced Viking Lander images. These colorful pictures were produced at the U.S. Geological Survey's center in Flagstaff, Arizona. Geologists are using them to study the rock and soil units on Mars — with the ultimate goal of deciphering the nature of the processes that have shaped the red planet.

What advantage do these unusual pictures have over the familiar natural-color pictures of Mars? On Earth, geologists routinely use color as a tool for identifying different layers — called stratigraphic units — of soil and rock. In addition, the color of soil or a rock often gives some information about its composition. Unfortunately, the natural-color pictures of Mars transmitted by the Viking Landers show a landscape so strongly reddish-brown that there's little obvious color variation. These images tell the viewer — or scientist — little more than the black and white pictures. But the color-enhanced images show that the soil on Mars is made of distinct, differently colored units, and that several different types of materials form the surfaces of the rocks.

How are these color-enhanced pictures produced? It begins when the Viking Lander camera scans a scene — one line at a time (bzz-whir-bzz-whir) — through color filters. Radio signals transmitted the original picture information from Mars to Earth, where it is now stored as numbers on computer tape. Black is represented as 0, medium gray by 32, and white by 63. To form color pictures, three images — one red, one green, and one blue — are needed. At the U.S.G.S. Image Processing Facility, a computer-controlled film writer makes three black and white transparencies from the numbers on the tape; the photolab combines these through colored filters onto color film to make the color pictures. If the computer is used to change any of the numbers that make up the three images, the colors in the final picture are changed.

Before the colors in these pictures can be enhanced, some bad data in the pictures has to be removed. When pictures are exposed with the camera settings optimized for the martian surface, bright areas in the sky and on the lander are overexposed, and any colors in these portions of the pictures are meaningless. Two computer programs are used to eliminate bad data from the images. First, the computer examines each image dot (or pixel, for picture element) by dot, and switches any bad data to black (zero). Then the computer compares the three pictures and where any pixel is zero, switches the corresponding pixels in the other images to zero as well. The areas of bad data in the images then appear as black patches in the sky and on the lander. None appear on the martian surface, showing that all of that data were properly exposed.

**This alien scene is not an astronomer's hallucination, nor the set for another cheap space opera. Instead, it is the familiar reddish landscape of Mars portrayed in computer-enhanced Viking Lander pictures.**

Varying the overall brightness of the three computer-generated images provides the simplest method of color enhancement. When the numbers are adjusted so that the average value for each image is the same, the average color in the resulting picture becomes gray. Balancing the color of Mars pictures so that the average surface color is gray makes the weak color variations present in the scene much more obvious. The gray paint on the Viking Landers appears a rich blue in these pictures; the sky, a pale earthlike blue. This shows that the pale orange sky of Mars is not as red as the surface. (It's as if we snuck a pair of blue sunglasses onto the Viking camera!) These equalized color pictures, however, are only the first step in enhancing the colors.

Before the colors in a picture can be exaggerated, the *color* information in the picture must be separated from the *brightness* information. To do this, the computer divides the numbers that form each picture by the average of those that form the other two. For example, the green image is divided by the average of the red and blue images. When the result is used to form a picture, relatively green objects appear bright, while relatively purple objects (purple is opposite green on the color wheel) appear dark. When this "greenness" picture is combined with the similarly produced "redness" and "blueness" pictures, the resulting color-ratio picture shows only the color variations present in the scene. (The result is similar to the effect of turning the contrast knob on a color TV all the way down.) Though unattractive and unnatural looking, these pictures are very useful. In them, it is easy for a geologist to compare the colors of objects that differ greatly in brightness.

With the color information separated from the brightness information of the original picture, the computer then uses a program to stretch the range of the numbers representing the colors in the picture. After this is done, the color information in the three ratios is recombined with the brightness information by multiplying each "colorness" ratio by the brightness of the original red image. Ideally, the average of the red, green, and blue images would have been used, but using only the red one saved computer time (and taxpayer's dollars) with little effect on the final product. The results are put onto computer tape, turned into three pictures, and assembled in the photolab into the color-enhanced picture. Only in these pictures does the martian surface display a wide range of colors, many times more than in the original natural and equalized color images.

What do these new versions of the Viking pictures tell us about Mars? For the first time, we can see that the soil at the landing sites consists of distinct units that differ in color, texture, and form. At the Viking 1 site, the uppermost of these units is the bright red soil. This appears to be a very thin layer of dust that covers most of the other soils. Where the red dust is thin or missing, the other soils show through. During Viking's first winter on Mars, dust storms in the southern hemisphere repeatedly stirred dust into the atmosphere, which then carried it around the planet. By the martian spring, most of the soil color differences at both landing sites had disappeared; thin, bright, red dust deposits coated the ground.

Curiously, the dust did not stick to rocks. Geologists concluded that this dust settled out of the atmosphere while the dust storms were dissipating. Perhaps the red dust, seen before winter at the first site, was the remains of a deposit formed a year earlier.

Under the red dust lie other units of soil. Viking 1 landed straddling the edge of a drift of dark, relatively blue soil. One of the lander's footpads sank into this drift, showing that this soil is soft, perhaps like cement powder. The other visible foot pad landed on hard, rocky soil and did not sink in. The rocky soil is the same dark blue color as the blue drifts, but because it has different texture, form, and mechanical properties from the drifts, it is safe to conclude that it is a different kind of soil.

Between the footpads, under one of the rocket engines, is a small patch of orange-red soil. This patch appears to rest on the rocky blue soil, and it may have been covered by the edge of the blue drift (the pictures really don't show enough detail to be sure). Apparently the rocket exhaust blew away the edge of the blue drift, and uncovered the underlying orange-red soil.

Here and there, in both rocky areas and on the drifts, are small patches with a relatively green-blue color. (Remember, these colors are enhanced; they are not the natural colors.) This may be a thin coat of dust that was deposited on both of the blue soils and then was covered by the red dust. One other soil is visible at the Viking 1 site. The cap of soil that rests on the boulder known as Big Joe near the lander is a dark red soil. This same soil also surrounds several clusters of boulders beyond Big Joe. Unfortunately, all the other soils in this region are covered with the bright red dust, so the relation of the dark red soil to the others cannot be seen. In total, we have discovered a series of five soils (red, green-blue, blue drift, orange-red, and rocky blue, plus another, the dark red which we can't relate to the series) at the Viking 1 site, some thin and some thick, all probably resting on the bottom unit of rocky blue soil.

**Opposite: Individual picture elements, or *pixels*, each one highly processed by computer for color enhancement, are distinguishable in this Viking lander photograph. The brilliant blue rock surfaces are in reality dark gray or red-gray in natural color, while brighter surfaces show up in these photographs as bright green. In the distance, bright red soil known as *duricrust* seems to coat most of the surface, although it appears to be no more than an inch or two thick. Photo courtesy of the U.S. Geological Survey.**

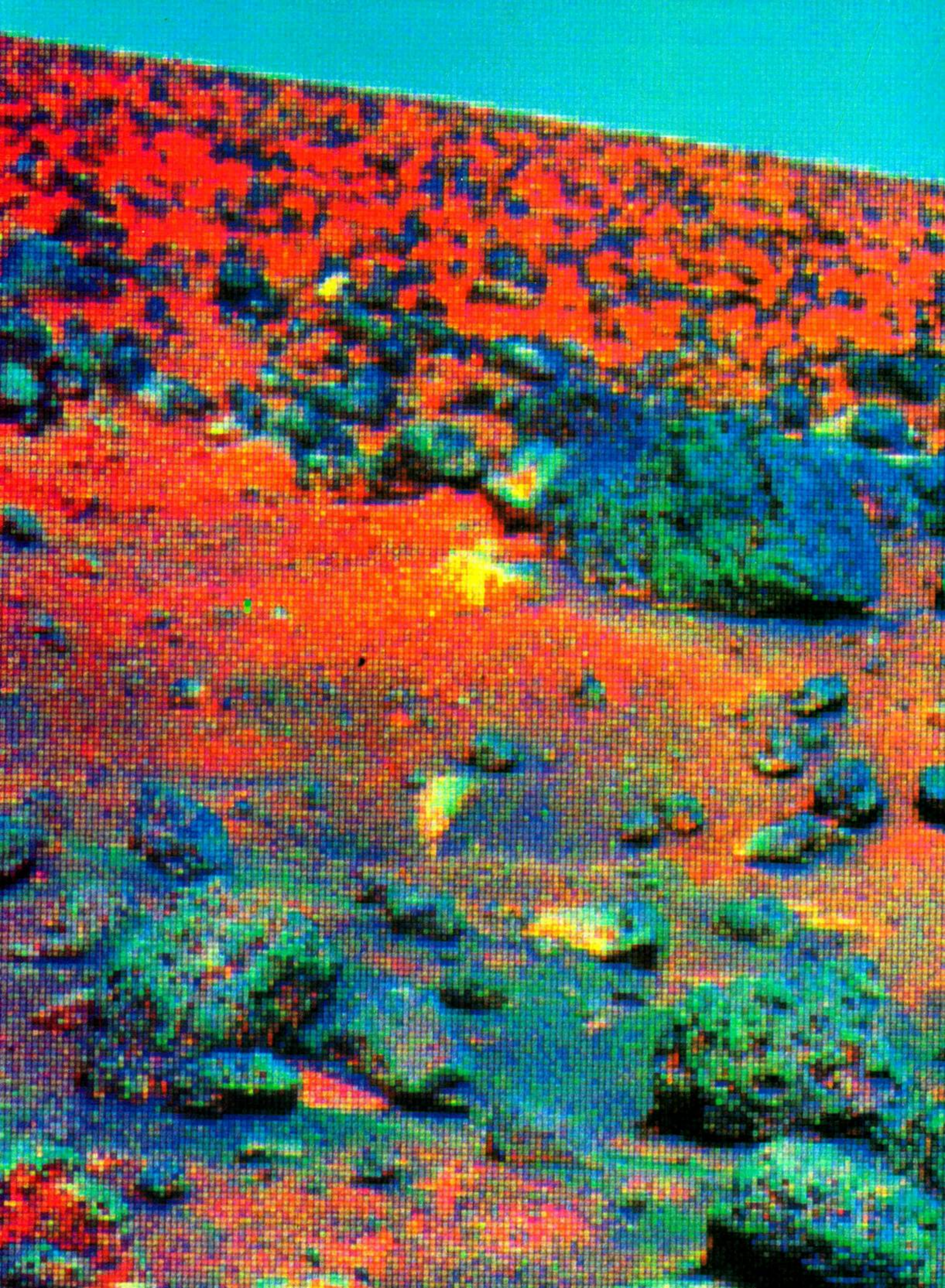
Nearly halfway around Mars, at the Viking 2 site, the pattern is surprisingly similar. Here, the deepest layer is again a dark blue soil, but it is only visible where the lander activity removed overlying soils. One patch of blue soil is exposed in a sample trench, while near the lander, more of this soil was exposed by the rocket exhaust and sprayed over the others and onto the right-hand footpad. Over it is a clumpy crust of red soil, called duricrust. This soil appears to be a thin layer, only a few centimeters thick, that covers most of the surface. In dips and hollows in the duricrust, and sometimes thinly coating it elsewhere, are small, scalloped blue-green drifts.

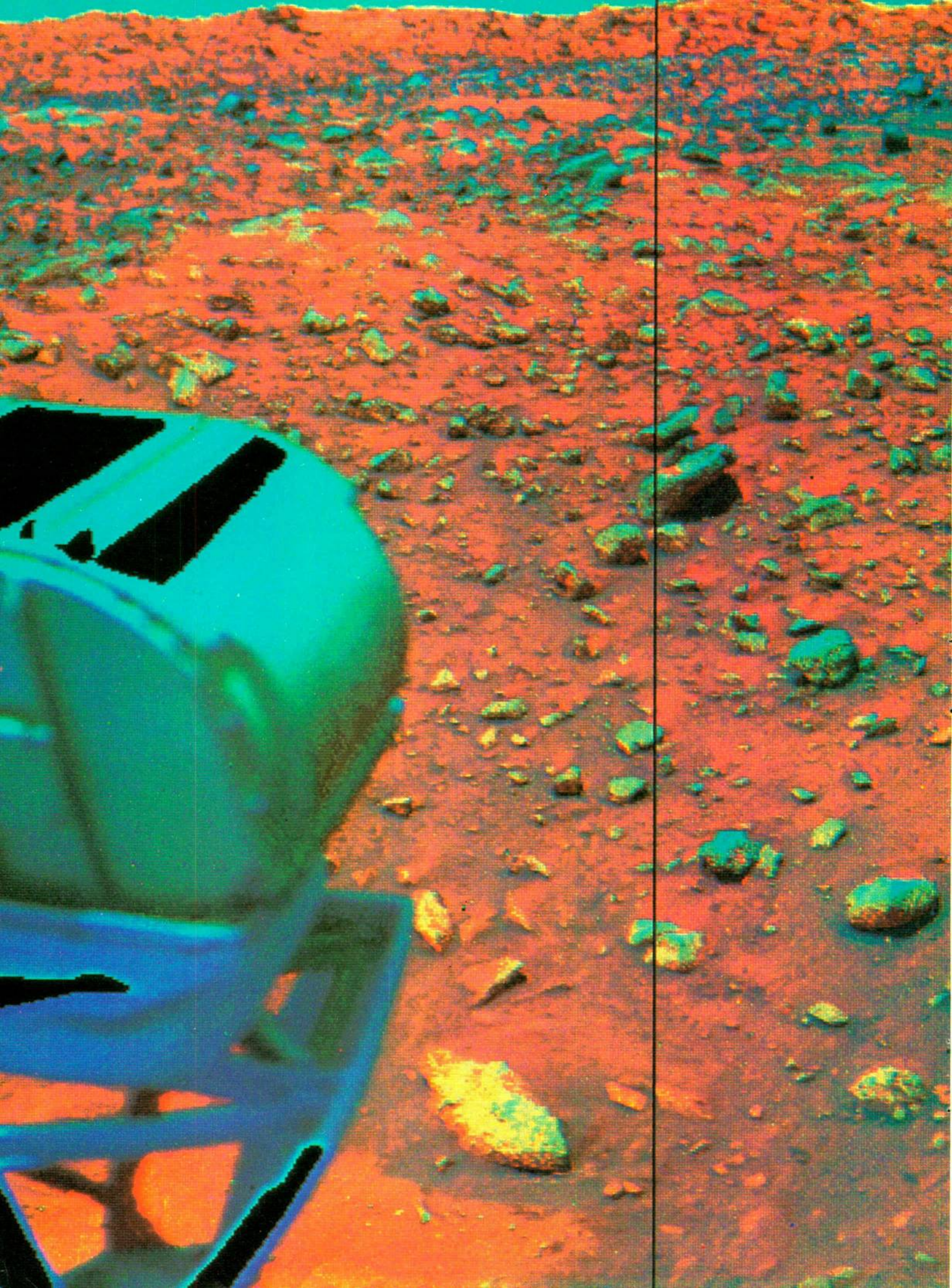
Farther from the lander are other drifts; these are the same bright red color as the duricrust. These drifts were the uppermost unit until all of the soils were coated with the thin layer of dust during the Vikings' first winter. The similarity between the two sites is surprising. On Earth, it would be very unlikely to find two randomly chosen sites, even in deserts, so similar.

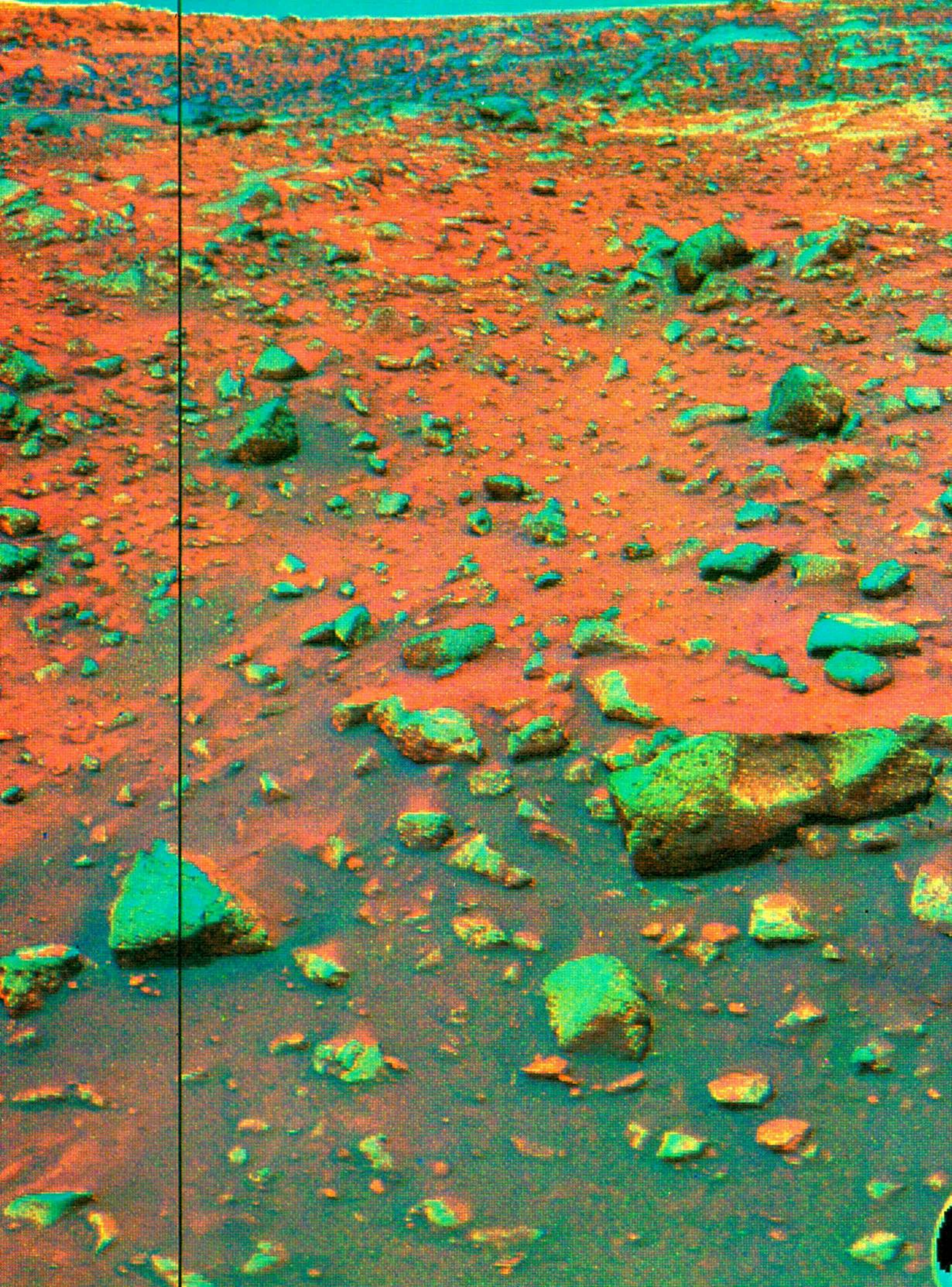
The rock surfaces at both sites also show a variety of colors. Dark rock surfaces — they appear gray or red-gray in natural color — are the least red surface features, and they appear very blue in enhanced color. Brighter surfaces are present on many rocks; these show up as bright green in the enhanced images. An outcrop of bedrock between Viking 1 and the Big Joe boulder shows this color, except for the dark tips and edges of the rocks which are dark blue. This suggests that the green material is some sort of thin, easily eroded coating on the rocks. Because there are no soils with a similar color at either site, it seems likely that the green coating was formed from the rocks by some weathering process. Exactly what it is and how it formed is unknown, and will probably remain so until samples are returned from Mars.

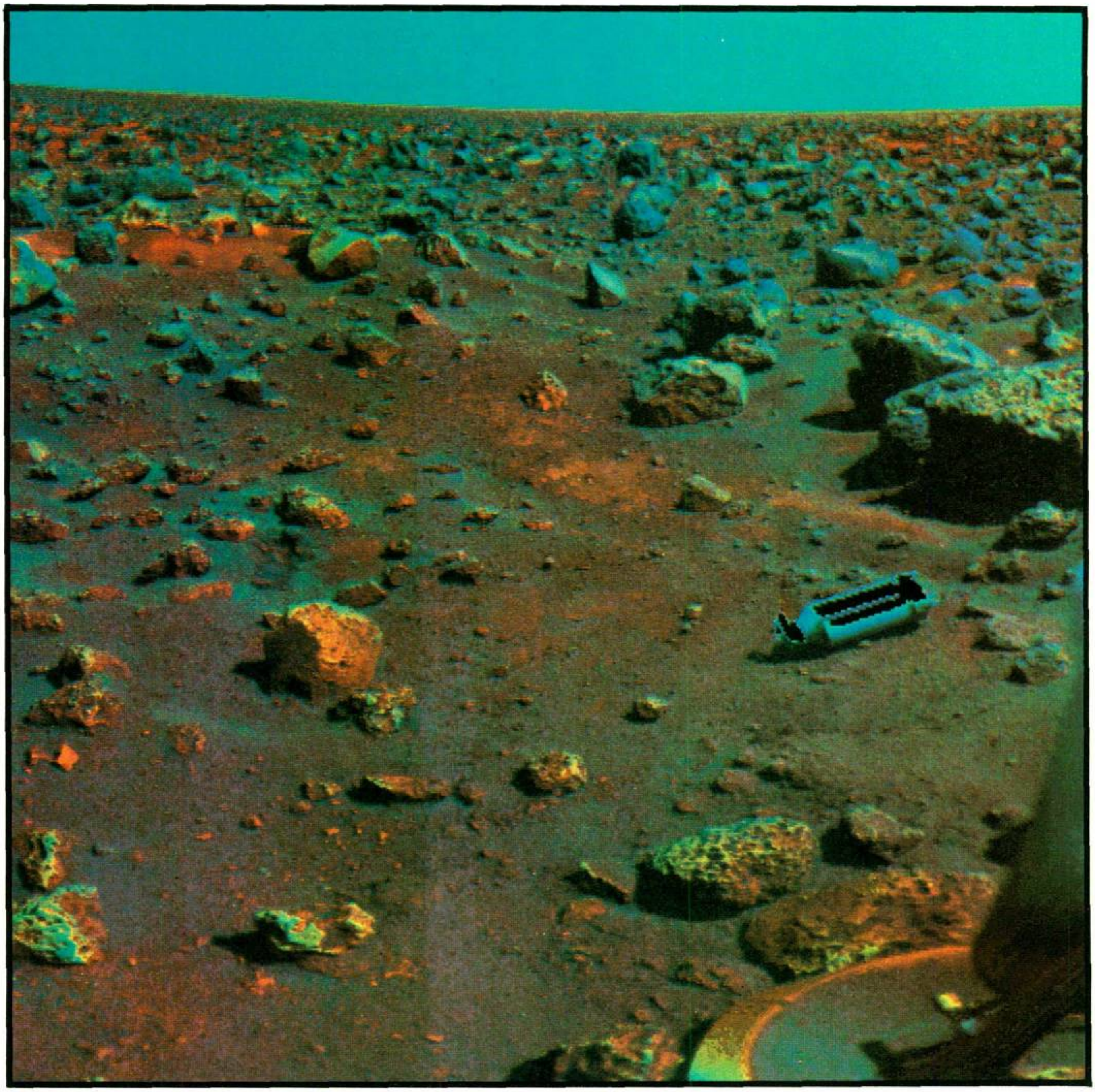
At the Viking 2 site, many rocks have surfaces of a third color: bright red. These surfaces are identical in color to the red drifts and duricrust. This suggests that this material is red soil sticking to the surfaces of the rocks. Soil on the rocks at the first site is much rarer. A few small cobbles near the lander appear to have coatings of orange-red soil, but the Big Joe boulder is the only large rock with a prominent coating.

**Pages 12-13: Subtle color shadings enhanced by computer processing enable scientists to determine the geological nature of martian rocks and soils in great detail. In this photograph, note the absence of red dust on the rocks in the scene, and how other soils are clearly *visible under the thin layer of red dust* in certain areas. A small patch of orange-red soil shows up under the portion of the lander at the extreme lower left. Photograph courtesy of the U.S. Geological Survey.**







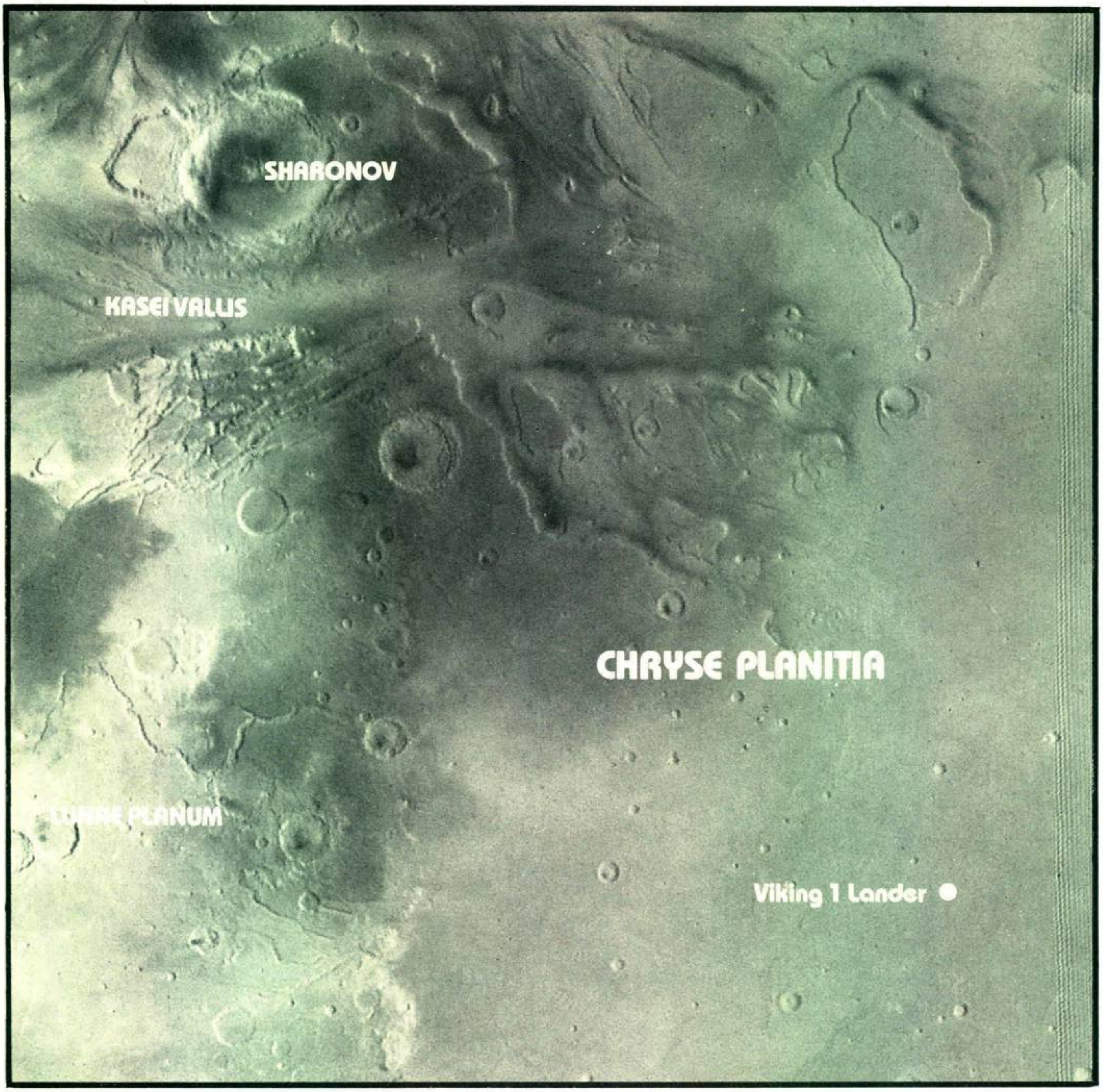


**At lower right above, one of the Lander's footpads rests on a relatively hard surface. Just above lies the protective cover for the Lander's trenchdigging arm. Note the complex shading of the visible soil, indicating a variety of different components. Photograph courtesy of the U.S. Geological Survey.**

The great similarity of both soil and rock surface colors seen at these two sites nearly on opposite sides of Mars makes it seem likely that these materials are typical of much of the martian surface. The presence of the green rock coatings at both sites suggests that whatever process forms it operates planetwide. The soils tell a related story: with no oceans or vegetated regions on Mars to trap wind-blown dust, it can be carried around the planet.

Perhaps thin deposits can be formed that cover almost the entire planet, building up year after year. Then, following a shift in weather patterns, the dust blankets could be partially eroded or covered with slightly differently colored soil. This hypothesis — it is as yet no more than that — can be tested by studying the color pictures of Mars taken from space by the Viking Orbiters. The first steps in that investigation are now under way.

With the aid of enhanced color pictures, it is now possible to make educated guesses about the history of the landing sites. Let's follow the chain of reasoning: Dr. Ray Arvidson and his co-workers have pointed out that the craters visible on orbiter images of the Viking 1 site show little evidence of erosion, and the rims of the few craters visible on the lander's horizon similarly appear fresh. No more than a few meters or tens of meters of erosion could have occurred without being obvious. But the fine details of the landscape near the lander are not those of a fresh lava plain. Nearby rock outcrops appear eroded



**Both Viking landing sites were located in relatively smooth plains such as *Chryse Planitia* above, much less rugged than the more complex terrain to the north and west. Surface exploration of the other geologic regions of Mars will undoubtedly result in exciting new discoveries. Photo courtesy of the U.S. Geological Survey.**

many centimeters. Other geologists have concluded — from the number of meteor craters formed on the lava plains of the Viking 1 site — that the lava flows formed a few billion years ago. The conclusion that Dr. Arvidson reached — that erosion of hard rock on Mars occurs very slowly — is almost inevitable.

The northern plains where the Viking 2 landed are much less cratered; in fact, the pictures from orbit suggest that as much as hundreds of meters of dust have been stripped from a thick mantle of soil that once covered the plains. Dr. Arvidson's group concluded that while solid rock erodes very slowly on Mars, deposits of dust could build up and be eroded hundreds or thousands of times faster.

From this and other work, a picture of Mars' history is slowly emerging: that of an ancient planet with a history dominated by the quiet deposition and erosion of dust, controlled by climate cycles many millions of years long, rarely punctuated by the occasional eruption of one of the great volcanos, the release of a catastrophic flood from melted ground ice, or the occasional impact of a great meteorite. This strange picture will be discussed, developed, modified, and argued over by scientists for years to come.

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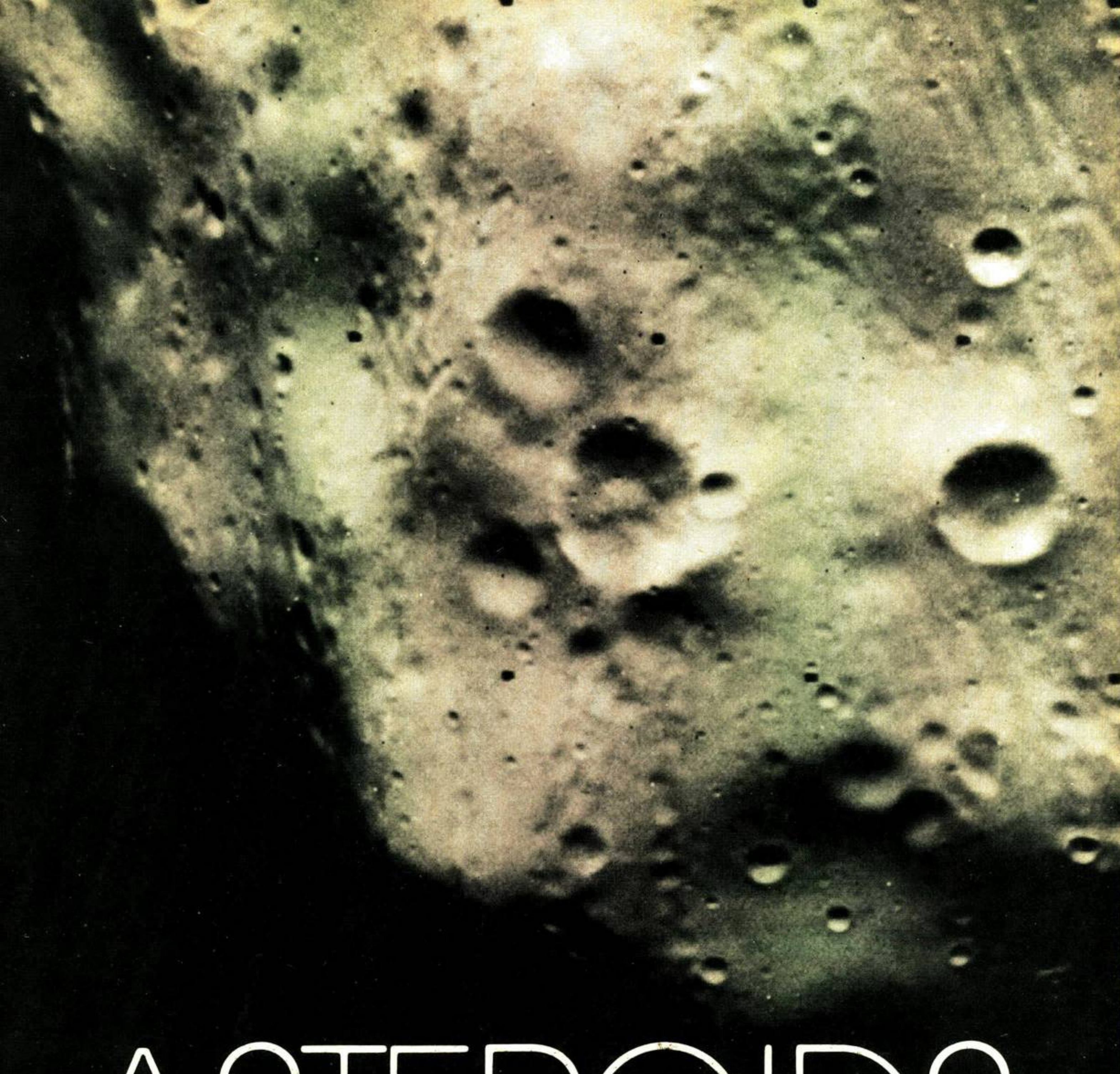
*Edwin Strickland is currently completing his work for the Ph.D. degree in planetary geology at Washington University in St. Louis, Missouri. As a member of the Viking lander team, he has worked on the staff of the United States Geological Survey in Flagstaff, Arizona.*



# ASTEROIDS:

## The Flying Mountains

by
Joel Davis

Giuseppe Piazzi wasn't even looking for them — he was compiling a star map and catalog. But on the first night of the first year of the 19th century, he found them.

What he discovered was the first of the asteroids, those flying mountains that ring the Sun between Mars and Jupiter. Unwittingly, Piazzi had upstaged a worldwide effort to find what many astronomers were convinced was a missing fifth planet.

From antiquity on, only five planets besides Earth were known: Mercury, Venus, Mars, Jupiter, and Saturn. These five "classical planets" remained the only ones known until 1781, when William Herschel accidently discovered Uranus. But even before that astronomers had looked at the arrangement of the planets and pondered. The large, empty gap lying between Mars and Jupiter intrigued many, including the famous Johannes Kepler. In 1596 he had published a treatise in which he wrote: "Between Mars and Jupiter I place a planet." He was the first astronomer of note to state publicly that a planet must exist in that mysterious gap.

**Not so long ago, asteroids were contemptuously dismissed as the "vermin of the skies" — now astronomers look to them for clues about how planets form and hints as to the early history of our solar system.**

### Titius and His Curious Law

More than a century and a half passed and Johann Titius published a detailed study of the relationship between the distances of the planets from the Sun. It included the first formulation of the now-famous *Titius-Bode Law.* (Johann Bode's name got tacked onto it because he cleverly popularized Titius' discovery and effectively made it his own for a long time.)

The Titius-Bode Law is really quite simple. Titius started by dividing the distance from the Sun to Saturn (the farthest-known planet at the time) into 100 equal parts. "Mercury is four such parts away from the Sun," Titius wrote. "Venus is 4+3=7 of them, Earth is 4+6=10, Mars 4+12=16." Titius continued the series by making the second factor in each successive equation double the previous one: from 12 to 24, 24 to 48, 48 to 96, and so on. The sums he thus arrived at were 4, 7, 10, 16, 28, 52, and 100. Continuing the sequence yields 196, 388, and 772 (4+192, 4+384, and 4+768); all very simple.

The notable thing about this numerology is that when these numbers are divided by ten, they correspond remarkably well to the actual distances from the Sun of the first 6 planets, taking the "astronomical unit" (AU) as a measuring stick. (The astronomical unit is the average distance at which the Earth orbits the Sun.) Mercury in fact orbits 0.39 AU from the Sun; Venus 0.72 AU; Earth 1.0 AU (of course); Mars 1.52 AUs; Jupiter 5.2 AUs; and Saturn 9.54 AUs.

The problem came with the fifth number of the series, 28. There just wasn't any planet between Mars and Jupiter, 2.8 AUs from the Sun. So, despite its appeal, the Titius-Bode Law remained not much more than an arithmetical curiosity.

Then Herschel discovered Uranus in 1781.

Uranus' average distance from the Sun in astronomical units is 19.18; the Titius-Bode Law had predicted a planet 196 units — that is, 19.6 AUs — from the Sun.

*Uranus fit.* (Well, almost. But few were prepared to quibble over the 0.42 AU difference.) That was enough for some astronomers; if it worked for Uranus, then there had to be a still-undiscovered planet between Mars and Jupiter, just as Kepler predicted back in 1596. The hunt was on.

Baron Franz von Zach tried to compute the orbit of the missing planet — and failed. In 1796 an astronomical congress was held at Gotha and French astronomer Joseph de Lalande suggested an all-out crash program to find the missing planet.

### The "Celestial Police" Organize

Four years later, at a conference in Lilienthal, de Lalande, von Zach, and Johann Schroeter pushed the plan into action. The sky was divided in 24 different zones, each "policed" by an astronomer keeping watch for the missing planet. Surely such a rational, organized program was bound to succeed.

Hardly! And ironically, the man who discovered the missing planet wasn't even looking for it.

Giuseppe Piazzi, an astronomer at Palermo, Sicily, was preparing an accurate star catalog. The one then in use was full of errors and Piazzi was intending to correct that.

On New Year's Day, 1801, he mapped a tiny point of light in the region of the sky he was surveying. When he checked his plottings the next night, he found it was gone. Instead there was a "new star" a little distance away. On January 3 he found a third.

By now Piazzi was sure the stars weren't stars at all, but rather one object on the move. He decided he had discovered a new comet and sent his findings to several colleagues — including Johann Bode. Meanwhile, he kept observing his new "comet" until February 11, when bad weather closed in.

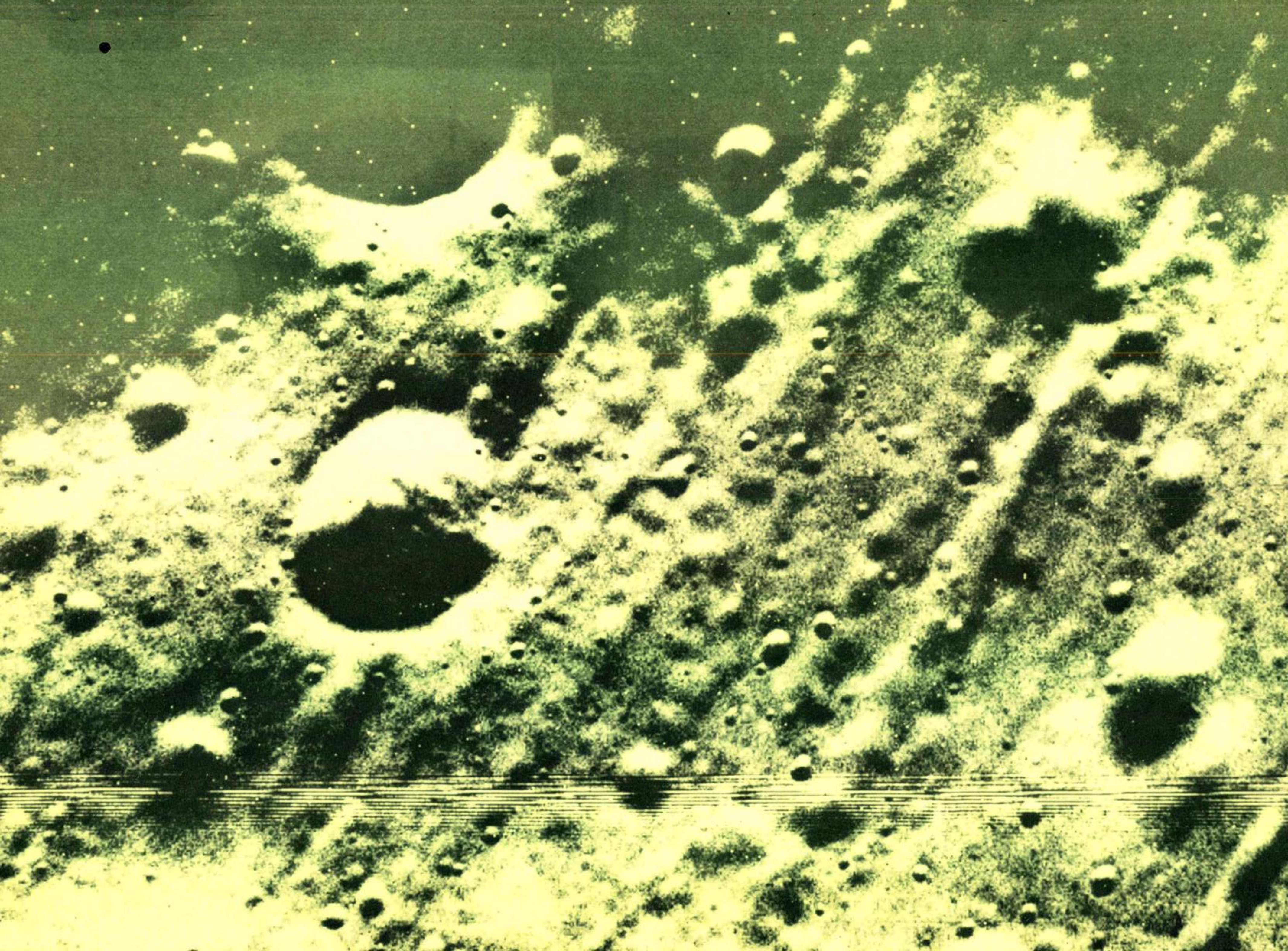
When Bode got the news he checked his charts and calculations and decided Piazzi's discovery was no comet but the sought-for missing planet.

Piazzi named the planet Ceres, after the patron goddess of Sicily. But by now it was lost. He hadn't made enough observations for astronomers of those days to plot its orbit. And Ceres was now too near the Sun for further observation.

It fell to a then-obscure young mathematician named Karl Friedrich Gauss to come up with the breakthrough.

Gauss was a true mathematical genius. He had just developed a new method of calculating the orbits of heavenly bodies using only a tiny amount of data, something no one else at that time had done. Gauss decided the Ceres problem was ideal to test his new

**The cameras aboard the Viking Orbiters circling Mars have given us exciting close-up views of its two moons Phobos (seen here and on the preceding two pages) and Deimos. For planetary scientists these are very important objects because they are likely captured asteroids — the first ever to be seen at close range. All photographs are NASA Viking images courtesy of Dr. Joseph Veverka of Cornell University's Laboratory for Planetary Studies.**



method on, and he worked out an orbit in October 1801.

He fired off his predictions on where Ceres should be found in the night sky. Baron von Zach himself, one of the instigators of the crash program to find the missing planet, located Ceres with them on December 7, 1801 and by December 31 had verified it. A few weeks later Heinrich Olbers, also using Gauss's numbers, spotted Ceres.

**Deimos nearly "full"**

The missing planet — missing twice, in fact — was now found. Its distance from the Sun in astronomical units: 2.76, just a tad off the 2.8 predicted by the Titius-Bode Law.

### And Then There Were Two...

But the drama wasn't over yet; in fact, it had just begun. On March 28, 1802, Olbers threw a cosmic monkey wrench into the proceedings by discovering a *second* planet. He named it Pallas. Gauss again worked his mathematical magic and there was no doubt: Pallas, too, was in orbit between Mars and Jupiter.

Then 18 months later, on September 1, 1804, Karl Harding discovered a third planet, which he named Juno. Three years later, on March 29, 1807, Heinrich Olbers found a fourth planet, his second one. It was named Vesta. All four had orbits lying between 2.3 and 2.8 AUs from the Sun — as the Titius-Bode Law had predicted for the one missing planet.

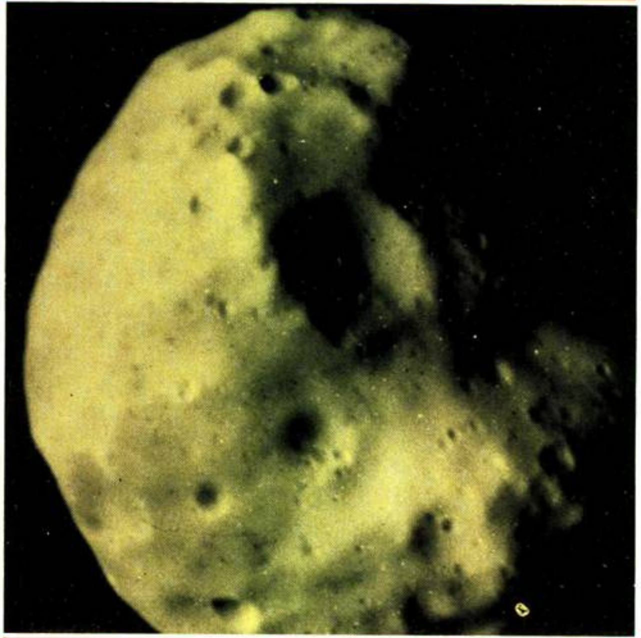
These new objects were small, hardly at all planet-sized. Ceres is only 620 miles in diameter, Pallas 334 miles, Juno 150 miles, and Vesta 330 miles. They are not really planets at all but minor planets, planetoids, or asteroids — "little stars."

How did the Titius-Bode Law fare in all this? Not too badly at first, but by 1846 it was in disrepute after Johann Galle found Neptune. Neptune lies at 30.06 AUs from the Sun, but the Titius-Bode Law said the planet next out from Uranus should be at 38.8 AUs from the Sun. The 8+ AU discrepancy was so bad that the "Law" was completely discredited.

In fairness to Bode, though, he probably knew the "law" wasn't a law at all. He once wrote that only empirical conclusions could be drawn from it. After all, the decision to divide the distance from the Sun to Saturn into 100 parts was quite arbitrary as was the decision to use the sequence of 0, 3, 6, 12, and so on.

But consider Pluto, discovered in 1930 by Clyde Tombaugh. This strange little object, which doesn't fit into any planetary scheme of things, has a mean distance from the Sun of 39.44 AUs — almost exactly the 38.8 AUs the long-dismissed Titius-Bode Law claims the planet beyond Uranus should have. Maybe we should take another look at the Titius-Bode Law.

Meanwhile, 38 years of fruitless searching went by after the discovery of Vesta. Then in 1845, Karl Hencke found a new asteroid he named Astraea. With that, the scramble for asteroids was on again in full force. It became popular for many astronomers in the 19th century, and not a year has gone by since without new ones being found. More than 2000 are known so far, with wonderful and exotic names like Hebe, Bamberga, Wladilena, Icarus, and Ra-Shalom.



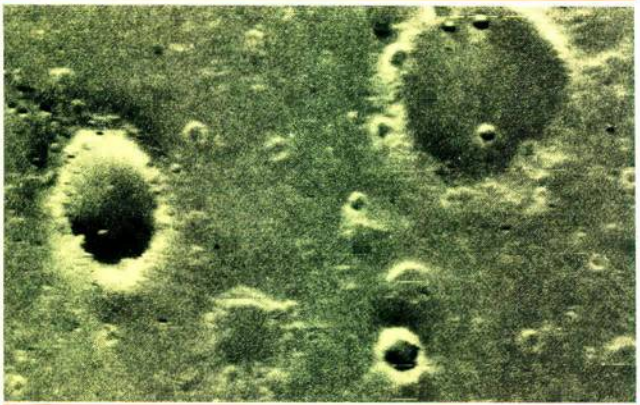
**Phobos' southern hemisphere**

### How Do You Make an Asteroid?

What are these strange objects, anyway? What are they made of? Do they come in different kinds? Are they the remnants of an ancient planet that exploded, sending pieces flying off in all directions? Asteroid-hunters have been asking these questions for a long time, and it's only recently that they've started getting some real answers. True to their past history, asteroids still have some surprises in store for us.

But first things first: Asteroids are identified by name and number. Until its orbit is confirmed, an object has a designation made up of the discovery year and two letters. The first letter tells which half-month it was found in, the second gives its order in that half-month. Thus 1976 AA was the first object found during the first half of January 1976.

When the asteroid's orbit has been accurately determined, it then receives a number corresponding to its official listing in the catalog of known asteroids: 1976 AA was number 2060. At this point its discoverer can give it a name. 1976 AA became 2060 Aten.



Close-up on Deimos: the big crater is 200 meters across

Most asteroids orbit the Sun between Mars and Jupiter. They range in size from Ceres' 620 miles to tiny mountain-size chunks — and probably even smaller. True to their eccentric reputation, though, not all of them inhabit that region. The moons of Mars are probably asteroids captured by the red planet eons ago. A family of asteroids called the Trojans travel in the orbit of Jupiter. The Apollo-Amor group have weird orbits that actually carry them inside the orbit of Earth. And the enigmatic object Chiron, orbiting between Uranus and Saturn, may be a newly-discovered member of a class of asteroids beyond that wide-ringed planet.

Some 95% of all known asteroids, though, do lie in the main belt and have orbital periods of from 2 to 6 years. Most of their orbits are of low eccentricity (i.e., not too far from circular) and lie pretty much in the plane of the solar system.

Many gaps exist in the main belt. The gravitational pull of Jupiter sweeps these 10 gaps clear of objects and thus creates 10 definite groups of asteroids, called "Hirayama Families." About a third of all asteroids in the main belt belong to such groupings.

### Exploded World, Or One That Never Was?

As many as 500,000 asteroids could exist. Where do they come from? Heinrich Olbers thought they were the remains of a full-sized planet that once existed between Mars and Jupiter, and which either exploded or was torn apart by the King Planet's gravitational field. This seemed a reasonable theory during Olbers' time. After all, the Titius-Bode Law was still strongly held and it had correctly predicted the distance of Uranus.

But after 1846, when the Law began to be questioned, astronomers wondered about Olbers' theory. Had there ever been a planet there in the first place? Perhaps asteroids were just pieces of matter that never had the chance to form a planet, because of Jupiter's influence. Soon this became the second major theory of asteroid origin.

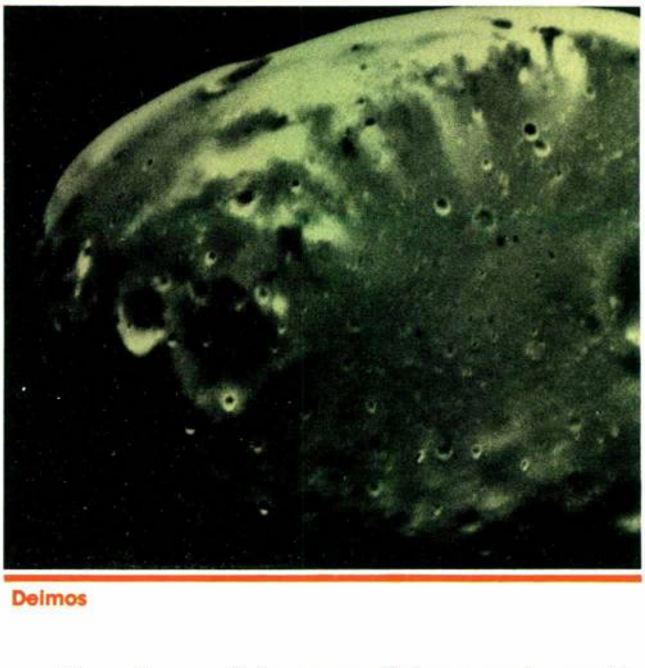
Theorists suggested yet another: that asteroids resulted from collisions of a few large bodies, and by now there's evidence this third theory may be the correct one.

Astronomers generally agree that asteroids are in a highly fragmented state. Most of them show periodic brightness changes, suggesting they are tumbling, irregularly-shaped objects. Photos of Phobos and Deimos, the asteroidal satellites of Mars, show just such irregular shapes. Studies indicate that 433 Eros is a spindle-shaped rock some 5 by 10 by 20 miles in dimension, turning end over end.

With this evidence in hand, astronomers now think the asteroid belt originally consisted of about 50 or so large bodies that formed, like the planets, early in the history of the solar system. But Jupiter's meddling gravity started them crashing into one another and breaking up. Only a few of the big original asteroids — like Ceres — remain. The rest have been fragmented over the ages into the slowly cartwheeling rocks we see today.

What asteroids are made of is also beginning to come to light — literally. By studying the polarization of the light they reflect and observing their reflectivity (albedo) in infrared as well as visible light, astronomers have started to unlock the mystery.

Asteroids, say some, fall into two main groups. The "low-albedo" asteroids are carbonaceous. They seem to be covered with dark carbon compounds and reflect little light. These are the most common. The other group, the "high-albedo" asteroids, seems to be mainly formed of siliceous materials — high in silicon compounds. They reflect more light than the low-albedo group.



Deimos

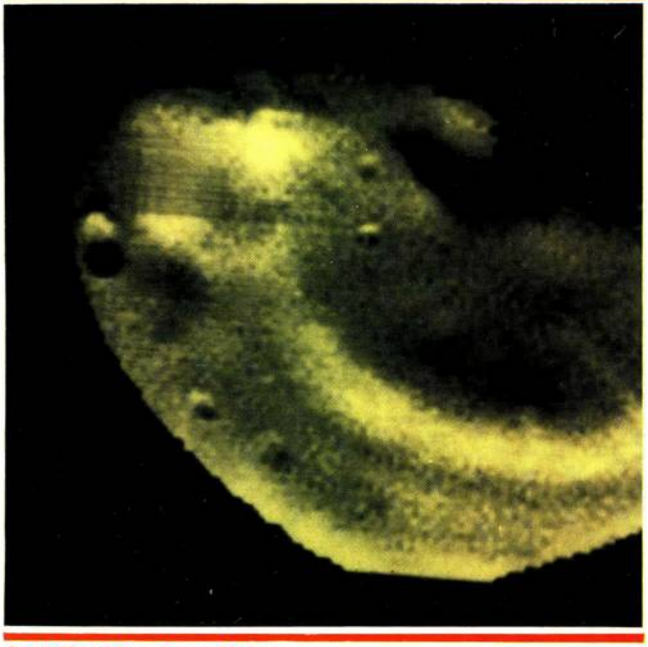
It's quite possible some of those early, proto-asteroids underwent internal melting like the Earth and other large planetary bodies did. They may have differentiated into metallic cores covered by stony-iron mantles and carbonaceous crusts. When they broke up in collisions, the dark outer layers would shatter off and become the low-albedo asteroids of today, leaving the lighter colored iron- and metal-rich cores behind. Thus the siliceous asteroids may be the fragments of the cores of those early giant asteroids.

### Why Do Some Act So Strangely?

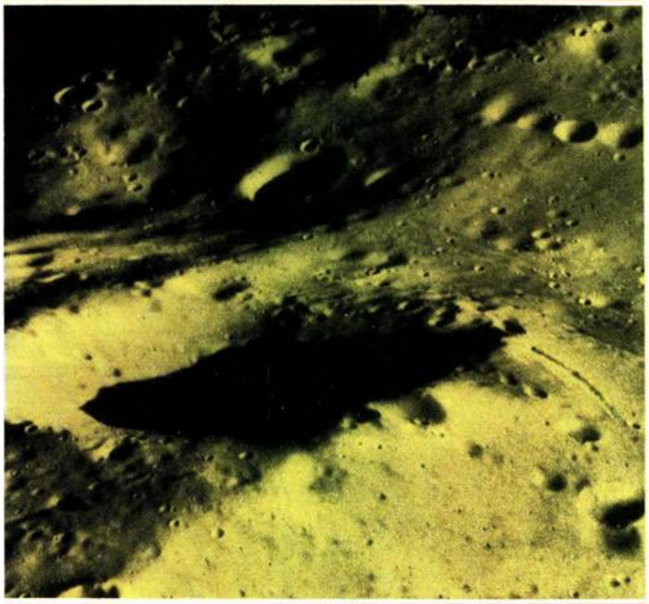
Though most asteroids lie in the main belt, others travel around a bit in unusual orbits. For example, a family of asteroids called the Trojans, occupy the stable libration points in Jupiter's orbit, 60° ahead and behind the giant planet (as seen from the Sun). Together with Jupiter they form an equilateral triangle with the Sun. These might be asteroids captured by Jupiter or they could be the remnants of the solar system's primordial material, tied to Jupiter for nearly five billion years. Two things are certain at least: several thousand of them exist, and their dark reddish surfaces are unlike other asteroids.

The Apollo-Amor group of asteroids has eccentric paths taking them inside the orbit of the Earth on their closest approach to the Sun. Like 1 Ceres, the first of the group was discovered and then promptly lost — this time for 41 years. 1862 Apollo was first spotted in 1932, but no orbit could be determined; it was not recovered until 1974. Some 28 Apollo-Amor asteroids are known so far.

The Apollo-Amor objects could be the remains of dead comets. After all, comets and their associated debris are the only other heavenly bodies that cross the Earth's orbit (apart from meteorites — which seem to be asteroid fragments anyway), and comet heads and the Apollo-Amor objects both have about the same size — from one to ten miles diameter. But they could also be asteroids flung from the innermost part of the belt into eccentric orbits by Jupiter's influence. That area — called the Flora Region after the largest asteroid in the area (8 Flora) — lies near a gravitationally unstable part of the belt.


A south polar view of Deimos

And then there's Chiron. Discovered by Charles Kowal in 1977, Chiron travels from just inside the orbit of Uranus to just inside that of Saturn, a decidedly unusual location for an asteroid. What's more, its orbit is unstable. Because of Saturn's influence, astronomers can trace Chiron's orbit back into the past and forward into the future only a few million years. Saturn's gravitational pull will eventually throw Chiron into a new, unknown path — perhaps even entirely out of the solar system.


Hall crater on Phobos

Is Chiron a comet from the Oort Cloud that surrounds our solar system? Did it get caught millions of years ago in its gravitational dance with Saturn and Uranus? Is it the first-discovered member of a new asteroid belt? Or is it an interstellar wanderer captured by Saturn? No one really knows.

### Moons, Too??

The Trojans are exotic, the Apollo-Amor family fascinating, Chiron mysterious. But asteroids have still another surprise in store: satellites. At least one — and perhaps two — asteroids may have companions in orbit around them.

On June 7, 1978, 532 Herculina occulted a star called SAO 120774. Two observers not only saw the star wink out when Herculina passed in front of it, they saw a second occultation of the star.

A probable explanation is that Herculina has a moon. It would be about 28 miles in diameter and orbiting about 620 miles from Herculina; Herculina is about 150 miles in diameter.

Then on December 11, 1978, 18 Melpomene occulted the star SAO 114159. No one spotted two blackouts of the star, but astronomer Richard Williamon, who should have been out of position to see the occultation of the star by Melpomene, saw an occultation anyway. There was no second, confirming occultation. But the blackout Williamon saw might have been caused by a satellite of Melpomene.

After 179 years, the asteroids are still surprising us!

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*Joel Davis is a science writer living in Seattle. His most recent article in ASTRONOMY was "Death of the Space Age" which appeared in the March 1980 issue.*

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# ASTRONOMY FORUM

## Have You Heard the Stars Tonite?

Music and astronomy being two of my dearest loves, I was delighted to read Aaron Isquith's essay "Listen to the Wandering Stars" (lovely title!), wherein a brief glance at the history of the harmony of the spheres precedes an appreciation of Holst's *The Planets*. Isquith mentions that this is one of the few pieces of classical music to deal with a celestial theme.

Rock music, on the other hand, has embraced such themes wholeheartedly. Now some may question its quality, but my own quite classically trained sense says that the best of rock music can stand on its own with any music of the twentieth century (and I offer a course for credit at the University of California, San Diego, where I attempt to demonstrate just such a musical judgment — skeptics are welcome!).

In any case, it is no surpise that rock music — using, as it does, the technology of electric guitar and bass, synthesizer, and a wide range of studio effects — should be so preoccupied with exploring the cosmic splendors.

One could begin with something simple and lighthearted like the Beach Boys' "Solar System," a charming paean to the planets and stars. Or one could listen to the several humorous musical treatments of UFOs by Jimi Hendrix ("EXP"), Creedence Clearwater Revival ("It Came Out of the Sky"), the Byrds' "CTA-102" (the first song about a quasar) and their classic "Mr. Spaceman." The approach in each case is not only satirical but clever in lyrics, melodies, and production.

A step up in musical seriousness would be the imaginative "Space Odyssey" by the Byrds. It is based on Arthur Clarke's story "The Sentinel" and preceded by some months the movie *2001: A Space Odyssey*. The thick texture of the Byrds' spacey sounds anchored by a deep bass line perfectly expresses the mysterious beauty of the cosmos. Or there's the ominous heavy metal rocker "Workshop of the Telescopes" by the Blue Oyster Cult to give a different view of the enterprise of astronomy, if that's indeed what it is about.

More benign, yet quite evocative of the loneliness of space is the Rolling Stones' remarkable little flight to Aldebaran, "2000 Light-Years from Home." Here the instrument being played is the modern recording studio, but textured voices and a subtle use of keyboards and strings beautifully expand the synthesized framework, so that one really does have a sense of the long cold flight to that red giant (actually only 68 light-years away).

**...my own quite classically trained sense says that the best of rock music can stand on its own with any music of the twentieth century...**

A step up in ambitiousness is Hendrix's remarkable hymn to our own lovely planet, "Third Stone from the Sun." The amazing tonal range of the guitar is utilized (nay, created) by Hendrix in layer after layer of sound of almost meditative splendor. It is truly the aural equivalent of the first photographs of the Earth from the Moon.

For a real stellar meditation, "Dark Star" by the Grateful Dead is unsurpassed. Over the foundation of the other five outstanding band members, lead guitarist Jerry Garcia and bass guitarist Phil Lesh lay dual counterpointed melodies that soar out as though carried on a giant solar windsail, weaving patterns as intricate as those a computer would have to figure for a literal journey to the stars, "through the transitive nightfall of diamonds." This two-part composition is, in my thinking, as complex and gorgeous as any comparable half-hour piece of music in our time.

After such a musical highlight, perhaps one is ready for a fluffier fantasy, the Paul Kantner Jefferson Starship's 23-minute *Blows Against the Empire*, a musical story of hijacking a starship in 1990. (Would that there were to be such a starship by then!) Expected (and understandable) social rage starts the musical action, but the real interest is in space travel, with an imaginative little synthesized musical shift from orbital to interplanetary flight, immediately followed by that loveliest of all star songs, "Have You Seen the Stars Tonite?":

*Have you seen the stars tonite*
*Would you like to go up on "A" deck and look at them with me...*

The electric bass supporting the strumming acoustic guitars and rolling piano, spacey electric guitars flitting in and out, sets the mood perfectly. Then the show is over, as the shift to the more powerful starflight occurs, leading to the final song, "Starship," with its true pounding interstellar motion, a beautiful song cycle, enjoyable to any music-loving astronomy buff.

I haven't even mentioned the

original masters of space rock, the classicists of rock music, Pink Floyd. Their very first album contains the powerful "Interstellar Overdrive," whose most appropriately awesome performance, pulsing with the strength of stardrive engines, actually appeared in a live version on a bootleg album entitled *The Midas Touch* (which also contains the best rocket lift-off song ever in the otherwise unreleased "Point Me At the Sky and Let It Fly" — the right stuff indeed!). Shortly after came Pink Floyd's "Astronomy Domine" and "Set the Controls for the Heart of the Sun," both pace-setting classics in the genre. Once again, as in earlier works discussed, the drive of rock rhythm combines with the delicate spacey electronic sounds, of which Pink Floyd are such masters, to create a listening experience which echoes the visual thrill of seeing Saturn's rings, Gamma Arietis' pair of perfectly matched diamonds, or M-42's far-flung lace. Astronomy is *domine* indeed! Even Pink Floyd's great album *The Dark Side of the Moon*, while not "about" space as such, certainly explores in a totally fearless manner the mortality of us men as suggested by the heavens.

But Pink Floyd's greatest legacy in this area is probably their inspiration of the continental electronic rock scene, which leads the way in that style. Sometimes these groups deal directly with spatial phenomena, such as Kraftwerk's pretty "Kometenmelodie 1" and "2." More frequently, the titular link is suggestive rather than literal, but the music is consistently acknowledged by those who hear it as a perfect counterpart to a night of viewing. On the excursions in observational astronomy I conduct, I invariably play such long pieces as Tangerine Dream's *Rubycon* or double l.p. *Encore Live* or Klaus Schulze's *Blackdance* or double l.p. *Cyborg*. With pieces of music such as "Voices of Syn," "Neuronengesang" or "Monolight," we are genuinely in that spatial realm of musica mundana ("the music of the spheres") heard but dimly by Robert Fludd (1574-1637), the most systematic of those thinkers who've tried to fathom the mystery of pleasing sounds in the cosmos.

"We are stardust, we are golden," sang Joni Mitchell. The beautiful and literal truth of that can be experienced any evening with eyeball to trusty lens, and, for me at any rate, with ear to trusty rock stereo speaker. Have you heard the stars tonight?

*John Mood*
San Diego, CA

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## An Interview with Ken Atkins

Today we're talking to Ken Atkins of JPL. Ken is deeply involved with the Solar Electric Propulsion System (or "ion drive") in the comet Halley/Tempel 2 mission.

ASTRO: How did the ion drive system win out over the sail?

KA: A lot of people ask that question. To me, it's a classic comparison between a sailboat and a motorboat. If you're in the business of trying to get to someplace within a certain amount of time, minimum amount of energy, minimum cost, especially in a commercial endeavor, you have to make a choice. Sea captains make this choice, and you won't see too many sea captains, at least as long as we have plenty of oil, using sailing ships.

ASTRO: Because Fulton invented the steamship, sailing ships eventually disappeared.

KA: The difference between a solar sail and an ion rocket is that an ion rocket can be pointed directly into the wind and driven right on into the target. A solar sail has to hold a specific angle relative to the Sun-line, tacking as it were in an orbital sense. It is therefore fairly inefficient converting the incident energy on it into useful propulsive energy.

And you may remember that the concepts that were generated for solar sails were huge beasts! They lend somewhat to the glamour and magnificence of such a thing, but from the standpoint of practicality, maneuverability, getting in the way of what you want to see, and also providing a good efficient propulsion to get you where you want to go, the sail just doesn't make any sense.

ASTRO: What about reliability? Is the sail not a large and relatively complicated kind of thing?

KA: Well, that was the technology part of it. There were two issues; one is performance. Performance-wise it doesn't compete. Technologywise it looked like it was very difficult and unfeasible to handle in a number of areas, not only from a standpoint of deploying, but also in maneuvering. In fact, the original concept (a square sail) was so difficult to adequately deploy, they eventually went to something called a heliogyro. It had blades on it which were many miles from wing tip to wing tip. Anyway, it got into the realm of the ridiculous.

ASTRO: How long have ion rockets been around?

KA: Well, at NASA for over ten years — since the early '60s. In fact, there's an ion rocket in orbit right now, launched in 1970, called SERT-2 (Space Electric Rocket Test 2). That engine is still running after ten years in space. It hasn't been run continuously for ten years, but has been operated off and on; whenever the sunlight has shone on the Agena rocket's solar cells, appropriately, the ion engine has been run. At the last six electric propulsion conferences — the International Electric Propulsion Conferences — the people from Lewis Research Center who operate that spacecraft have given a report on it. Mr. Bill Kerslake, the guy at Lewis Research Center who has charge of that satellite, just gave a paper recently on the plans for two spacecraft during the coming year! And that's a very early vintage rocket.

ASTRO: And they can turn this thing on and off and point it where they want to? Obviously the fuel's no real problem.

KA: Fuel is not a real problem. Interestingly, there was a paper at the International Electric Propulsion Conference held last week about the trade-off between specific impulse and time. You can imagine that a system that has a very high specific impulse and a very low thrust, which is the class of machine that a solar sail or an ion rocket is, is efficient. But if you need more thrust density, efficient use of the propellant may be less important. So one of the things that's a bit paradoxical is that we would like to drive specific impulses in ion rockets to a lower level to raise thrust density. The reason for that is if you're trying to move from lower Earth orbit to higher Earth orbit, or Earth to Mars in a "ferry" mode, time is money. So you can afford to pay a little more in terms of expended fuel as long as you can adequately carry it, because you still have fairly high efficiency but get there faster.

It's just like most of the people around here: although we recognize that 55 m.p.h. saves us gasoline, I defy you to go out on the freeway and find too many people driving that speed today.

ASTRO: Especially the trucks!

KA: Truckers know that 55 saves them gasoline. But the faster they can deliver that load, the more loads they can deliver and the more money they can make. They're willing to take that trade-off in fuel cost against time. And so specific impulse, or efficiency in fuel, peaks someplace.

ASTRO: You are part of the comet

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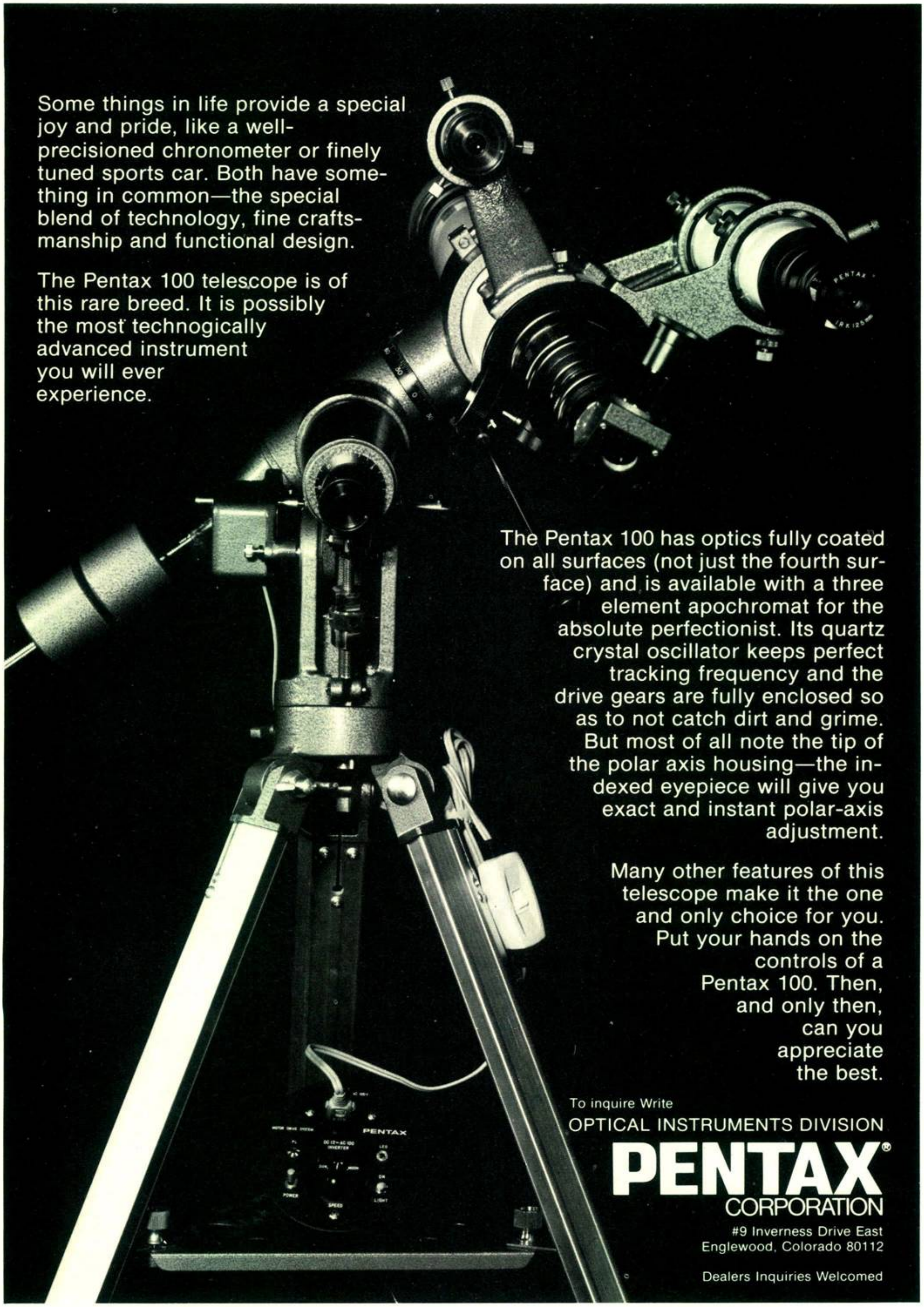

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Halley/Tempel 2 team. How do you see that mission?

KA: In science there is the growth of knowledge, and that's something we're all for. However, there's another thing: the "exploration ethic" or the innate desire and curiosity to find out what's over the next hill. All of that, of course, adds to human knowledge, ways to determine our place in the cosmos, in the grand scheme and order of things. So, while science is certainly the key rationale for wanting to understand a comet, it's also probably a helluva lot of fun to go there and see what one is.

ASTRO: Scientists are very much like that. They enjoy finding out!

KA: I think that the comet mission has a lot of "pizzazz" too. It's going out to some kind of a target that's got that kind of mystic attractiveness about it. Nobody knows anything much about them, so it's like opening up a new frontier. And there aren't that many of those left inside our own solar system.

ASTRO: And it also ties in...

KA: Yeah, with the current craze for science fiction and the interest born of *Star Wars*. It goes all the way from Jules Verne science fiction to science fantasy — to *Buck Rogers in the 25th Century*. And here we have a propulsion system that fits right in with that group of cultural folks: the ion drive. It's been around in science fiction for a long time and now it's something that we can point to with pride, sort of saying "I told you so," and that piques people's interest.

ASTRO: There are a lot of people out there interested in space.

KA: One thing I hope they'll pick up on: space exploration since Apollo has had a rough road to travel, in terms of a level budget and decreasing inexpensive opportunities. We've used up the number of inexpensive opportunities. There's also been a great deal of competition for the general public's attention in terms of what I'll call "problems that impact people's lives." It's hard to coolly sit back and contemplate the galaxies and the stars while you're sitting in a damn gas line or when your paycheck is being eaten up because you have to buy groceries that cost more this week than they did last week.

ASTRO: Space exploration has had a hard time.

KA: The glamour that was attached to a congressman who got himself on the space committee of the Congress in 1957 is no longer there. They all want to be on the energy subcommittee or the whatever subcommittee, somewhere where the action is.

I think that your group of readers forms a constituency. I hope they talk to their elected representatives about the importance of the missions, like the comet mission, as an extremely important function. If they believe in it, if they think it should be done, if they like it, then they shouldn't sit there in their closets and think it. They should say so!

ASTRO: We spend more on cigarettes and cosmetics every year than we do on all the space exploration that you could dream up.

KA: And all I'm saying is that it would be very helpful if your readers could somehow get out a message that said: "We care." There are a lot of people out talking about nuclear power, people in the streets rioting about the Shah, and I'm not saying that we should end up in the streets, but at the same time there is a level of what I call intellectual activism, logical discussion, letters, and so on, that can impact and have a good effect on where the space program goes. And I would encourage them to exercise that activism in whatever way they see fit.

ASTRO: Do the scientists themselves hurt their own cause?

KA: Yes. We tend to be somewhat arrogant about science. And if you want to get people to pick up on your goals and your ideas, you've got to enlist them, not teach them or preach to them.

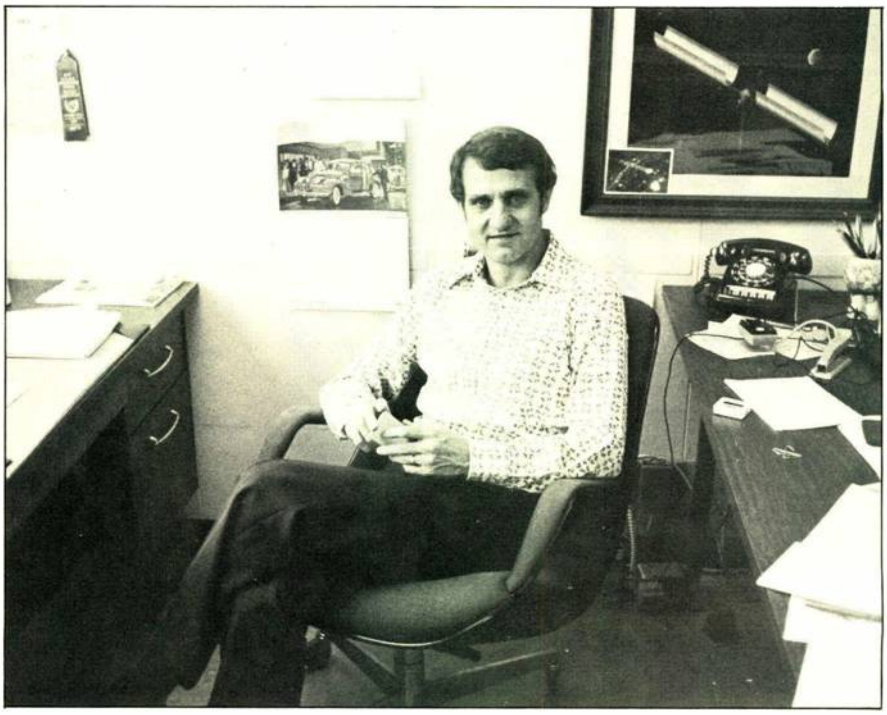
Science tends to talk a lot to science. We talk to each other. We've been very good at talking in terms of jargon and scientific terms and so on, and the general public looks at scientists as guys who sit around near computers and talk equations, so they tend to write them off to a certain extent.

ASTRO: And I've seen that a lot of the mission results never really get out. Even the reporters can't follow it.

KA: Good point. Look back at the past space exploration — especially Apollo — and ask yourself what came out of that space exploration. Where did it all go? Did the taxpayers get any benefit out of it? And in terms of what? If you do that, the only place that the public got an appropriate kind of exposure to Apollo was through *National Geographic*. That's where the general public can relate. That's where they'll look back and say, "That was either good or bad." They will judge us — and science — by that magazine. Not many people read *American Scientist*, or the *Astrophysical Journal*, or *Science*, or *Icarus*, or any of the others that pile up on the learned bookshelves of the people in science. These simply don't relate to people in "the real world" — people that are out there paying the taxes and grumbling about space, or welfare, or the politicians, or whatever. Without that constituency I don't see where we can go but down the tubes. ASTRONOMY helps.

ASTRO: ASTRONOMY readers aren't quite "the general public." They know quite a bit more — and they're interested in what happens.

KA: I think you've got a good group of people out there.



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eye on the sky

# venus: beacon in the west

## the wanderers

If you watch the sky at all, you've undoubtedly seen it in the western sky not long after sunset. In fact you can't miss it, it's so bright. Your nonastronomical friends may have been asking you about the UFO — and your answer, "That's Venus," brought a disappointed, "Oh, it's just a planet."

**Venus** is about to give up its starring role in the evening sky show. While at the beginning of the month it sets three hours after sunset, by the end of the month it'll set in just an hour. May is the last full month when you can see it easily; on the 15th of June, Venus will pass between the Earth and Sun and move into the morning sky.

Go out each clear night about 45 minutes after sunset and take careful note of its position; you'll see it slip day by day ever lower in the sky.

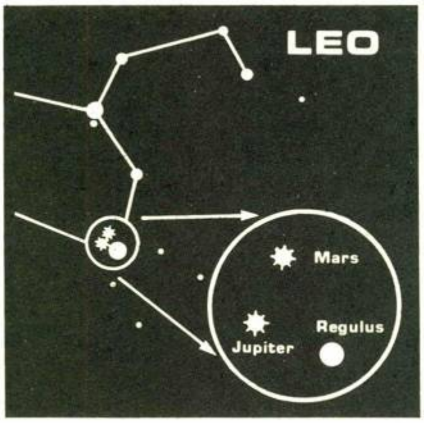
Venus is also increasing slightly in brightness and will reach maximum brilliancy on the 8th. As Venus draws closer to us, overtaking our Earth in orbit around the Sun, it looms larger and larger. At the same time, because it is turning more and more of its dark hemisphere towards us, the amount of sunlit Venus we can see grows smaller and smaller.

Ever since Venus emerged in the evening sky, it's been getting brighter because the increase in size has predominated. But after the 8th, the growing shadowed part gains the upper hand, and so Venus' brightness peaks on that date. Maximum brightness always comes about 40 days before and after the time called *inferior conjunction*, when Venus passes between the Earth and Sun.

**Mercury**, the Sun's innermost planet, won't be visible until very late in May, but get yourself prepared for an opportunity to see it fairly easily in June. Mercury will pop over your horizon in the west-northwest during the last week of May. Venus, descending toward the Sun, will appear to be on a collision course and will pass Mercury by on the evening of June 1st.

If you compare the Star Dome map with the sky, you'll notice three bright interlopers distorting the familiar outline of Leo. The dimmest of these (also slowest moving and pale yellowish in color) is **Saturn**; the medium bright one that's red-tinged is Mars, and the gleaming white object is Jupiter.

Saturn is the most easterly of the three, and lies below and to the right of Denebola, the star marking the tail of Leo. At present and for most of the next year, Saturn is unusually dim. Its rings are now turned almost edge-on to us here on Earth, so all its brightness comes from sunlight reflected off the ball of the planet. As the rings slowly open up to maximum — wait until 1986 — Saturn will be growing steadily brighter as we begin to see more light reflecting from them.



Over the past 6 months, **Mars** and **Jupiter** have been engaged in what astronomers call a "triple conjunction." Both planets were behaving like any other planet farther from the Sun than we are: first moving east among the stars, slowing to a halt at the eastern stationary point, then moving westward (or retrograde) against the stars, stopping at the western stationary point, and lastly resuming normal planetary motion eastward again. What's so interesting and spectacular now is that both Jupiter and Mars are so close together in the sky.

Since last December, Mars (which moves faster) has passed Jupiter twice: once on December 13, 1979 going east; then again on March 2, 1980 going west. The third and last conjunction comes on May 4th.

Mars and Jupiter form a cozy pair near Regulus, the brightest star in Leo. On the evening of the 3rd to the 4th, they'll be less than 1½° apart (3 moon diameters apart), making a tight little triangle with Regulus. This will be a very pretty event to watch for! After passing Jupiter, Mars will continue its motion eastward, overtaking Saturn late next month.

Triple conjunctions between Mars and Jupiter are rare events: the last such was over 140 years ago.

## the starry sky

A good time to begin an acquaintance with May skies is around 9:30 to 10 p.m., or about two hours after sundown. By then twilight is over and the sky will be as fully dark as local lighting permits. Go outside and start your eyes adjusting to the dark — about 15 minutes spent in darkness will do the trick. For reading star maps, carry along a dim red-lensed flashlight.

Sinking below the western horizon are the starry groups of winter, while spring constellations reign prominently. **Auriga**, marked by bright Capella, and **Gemini**, featuring Castor and Pollux, are both slipping low. **Sirius**, *the blazing heart of Canis Major*, has set and **Procyon**, the Little Dog's beacon star, will soon follow.

**Even ordinary camera equipment will record impressive sights: Hal Jandorf used a 135 mm lens, GAF 200 film, and a 1 second exposure at f/2.8 to get the Moon and Venus.**

The "normal" skies of spring look very different this year because Leo — for many people the very symbol of spring constellations — is startlingly distorted with bright planets.

The best "jumping-off point" to find your way around May's skies is the **Big Dipper**, which nearly everyone can recognize. Look for the Dipper turned "upside down" high in the northern sky.

The two bright stars at the end of the bowl are the "pointers" and a line from them extended about five "pointer-spaces" toward the northern horizon will pass very close to **Polaris**, the pole star. Polaris lies very close to the north celestial pole, and so all the other stars in the sky seem to circle around it.

Next, trace out the handle of the Dipper and when you get to the bend, stop for a good close look at the star you see there. (It's the second star from the end.) Can you see a fainter star accompanying the bright one? The little star is named **Alcor**, the bright one **Mizar**, and the Arabs, from whom the names come, reputedly used finding Alcor as a test of eyesight.

Following the handle of the Dipper out and down in a curve (go about another handle and a half) will bring you to a bright yellowish-ruddy star: **Arcturus**. (Remember the mnemonic "Follow the arc to Arcturus.")

Arcturus is the chief star in an elongated constellation called Bootes (the herdsman), and is the fourth brightest star in the sky. It is also relatively close to the Sun, being at a distance of only about 35 light-years. The other stars take the shape of a kite or ice-cream cone extending toward the northeast.

If you continue that curving line from the Dipper's handle through Arcturus about an equal distance, you'll "speed on to **Spica**," the brightest star in the constellation Virgo. Spica is a white star, much hotter and brighter than the Sun, 220 light-years away.

The rest of the constellation is outlined by a rough rectangle of less-bright stars spread to the east and west above Spica. None are really prominent and under a typical urban or suburban sky, you'll have trouble tracing the shape of the group. If you're observing from better suburban or rural places, the view is a lot better.

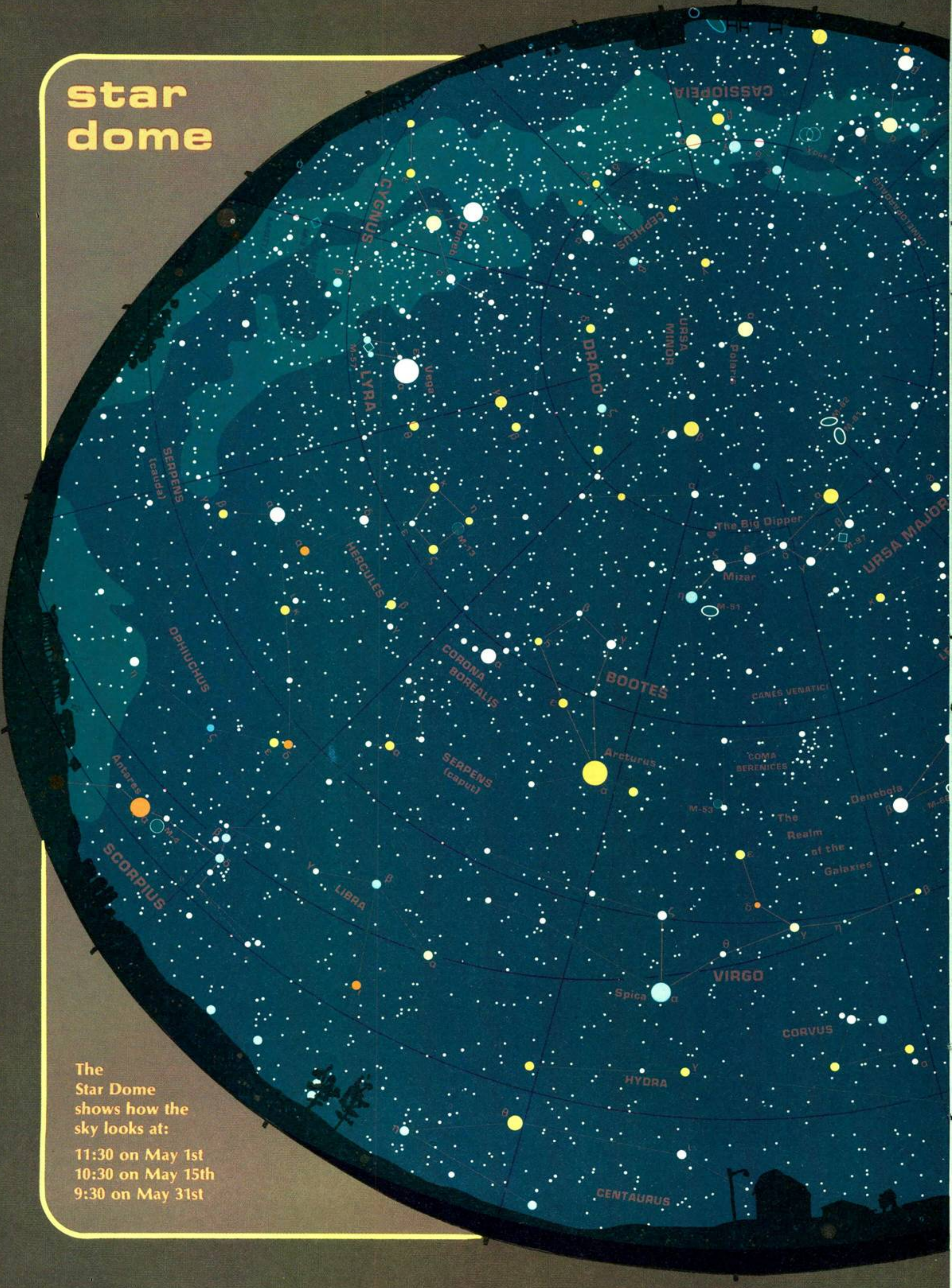
**Virgo** is a zodiacal constellation. Along with the other eleven zodiacal constellations, it lies astride an imaginary line called the *ecliptic*: This is the path the Sun "moves" along each year as it appears to traverse the heavens. For example, every October 25, the Sun passes about 2° to the north of Spica.

The ecliptic is really the projection of the Earth's orbit on the sky. Since the orbits of the other planets also lie near the ecliptic, you'll never have to look too far from it to find them.

Now look low in the west and you'll see bright Venus. It, too, is on the ecliptic, in **Gemini** (the twins). In between Gemini and Leo lies another zodiacal constellation, **Cancer** (the crab), which has no planets in it now.

With all the planetary comings and goings in Leo, you may easily pass the backdrop stars by, but don't. Trace the outline of the beast: start at **Regulus**, a bluish-white star 84 light-years distant and move up the reversed question mark — Leo's Sickle; these stars mark the lion's head and chest. To the east, above Saturn, is a triangle of stars with its eastern point at **Denebola**; these are the lion's hindquarters. To the lower right of Regulus are several dimmish stars in which some people

# star dome


CASSIOPEIA
CAMELOPARDALIS
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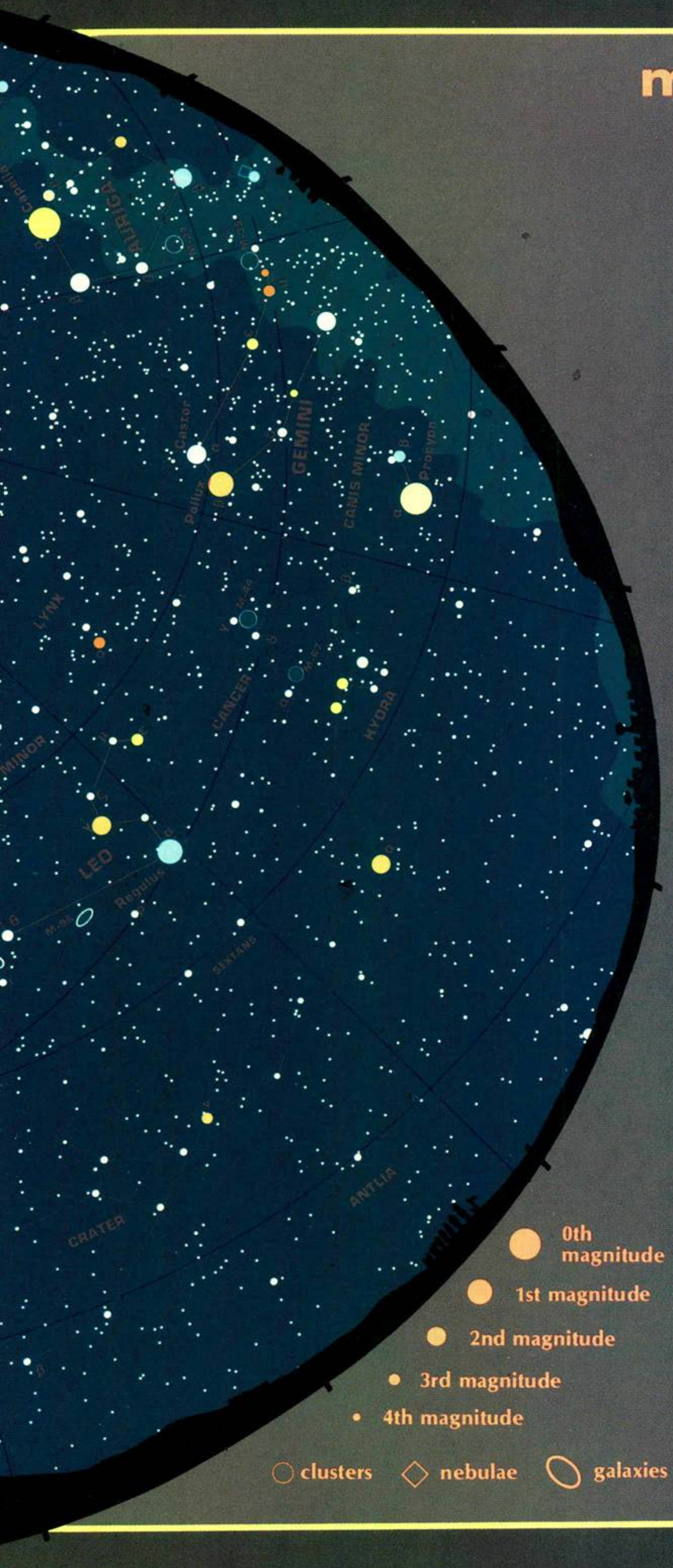
CYGNUS
Deneb
LYRA
M-57
Vega
DRACO
URSA MINOR
Polaris
M-82
M-81
SERPENS (cauda)
HERCULES
M-13
The Big Dipper
M-97
URSA MAJOR
Mizar
M-51
OPHIUCHUS
CORONA BOREALIS
BOOTES
CANES VENATICI
Arcturus
SERPENS (caput)
COMA BERENICES
M-53
Denebola
The Realm of the Galaxies
Antares
M-4
SCORPIUS
LIBRA
VIRGO
Spica
CORVUS
HYDRA
CENTAURUS

**The Star Dome shows how the sky looks at:**

11:30 on May 1st
10:30 on May 15th
9:30 on May 31st


Capella
AURIGA
Castor
Pollux
GEMINI
CANIS MINOR
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LYNX
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CANCER
M-67
HYDRA
MINOR
LEO
Regulus
M-95
SEXTANS
ANTLIA
CRATER
0th magnitude
1st magnitude
2nd magnitude
3rd magnitude
4th magnitude
○ clusters
◇ nebulae
⬭ galaxies

# may sky almanac

| | |
|---|---|
| **3rd** | Eta(η) Aquarid meteor shower. This is a stream of meteors coming from the "Water-Jar" of Aquarius. Look for a few fast, yellow meteors in the early morning sky (4 a.m. to dawn). A nearly full moon will brighten skies and wash out a lot of meteors, though. |
| **4th** | Mars passes just north of Jupiter; both are near Regulus in Leo. |
| **7th** | Moon is at last quarter today. Look for it setting in the west after sunrise on the next few mornings. |
| **8th** | Venus is at maximum brightness this evening. |
| **12th** | Moon is at perigee (closest approach to Earth: 225,059 miles). |
| **13th** | Mercury is on the far side of the Sun (at superior conjunction), directly opposite the Earth and hidden in the Sun's glare. |
| **14th** | New moon — good time to observe from a dark sky site! |
| **16th** | A thin crescent moon will be south of Venus this evening. |
| **21st** | Moon is at first quarter; can be seen in the east starting in the early afternoon. It's also near Mars and Jupiter in Leo. |
| **23rd** | Tonight the Moon will be to the east of Saturn. |
| **24th** | Moon is at apogee (farthest distance from Earth: 251,551 miles). |
| **25th** | Start looking for Mercury tonight. It'll look like a reddish star very low in the west-northwest; if you can't find it, try again tomorrow evening. |
| **29th** | Full moon — washed-out skies! |

see curled-up forepaws. And there you have it — one heavenly kitty!

Between Leo and the bowl of the Big Dipper lies a "new" constellation, **Leo Minor**. Created by the astronomer Johannes Hevelius in 1690, it's a faint, characterless group of dim stars best looked for under really dark skies.

By around 11 p.m., interesting things are happening in the eastern sky. Several bright stars — ruddy Antares in the southeast and the familiar Summer Triangle of **Vega**, **Altair**, and **Deneb** — are coming into view. These fine attractions will be star performers in a month or two, so if you want to get a jump on the seasons, simply stay up late.

The sky at 4 a.m. in mid-May is the same as the mid-July sky at midnight — or that of mid-August at 10 p.m. For each two hours later you stay out, you get a month's preview.

## skylore

In most of the country, May is the month of "high spring," when the last frosts are past and nature rushes forward with new growth. Flowers abound in a multitude of colors, trees glow with the fresh green of young leaves, and the first shoots of garden crops thrust up from the bare plowed ground into the warm breezes and sunshine.

May Day, the first of May, is an ancient pagan celebration of the fertility of spring. Although little observed now in most western countries, it has become a major festival in the communist world because the date was long ago selected to commemorate the solidarity of the working classes.

Traditionally, however, the first custom that comes to mind in association with May Day is that of the Maypole. But many are unaware of the details of the Maypole observance, no doubt because of their prurient character. The Maypole is a survival of ancient spring fertility rites, and in former times this quaint decorated pole and its accompanying weaving dance was the prelude to an orgy!

One does not have to view human behavior through Freudian-colored glasses to see the Maypole itself as a phallic symbol. But if there is any doubt about this, the rites surrounding it quickly remove them. According to the tradition, an even number of colored ribbons or ropes (often decorated with flowers) are attached to the top of the pole. An equal number of young men and women — single, of course — take their places in a circle around the base of the pole, each grasping the ends of one of the ribbons. When the dance begins, they circle the pole, the men moving in one direction while the women dance in the other. They weave in and out as they dance, alternately passing each other on the left and the right, which also braids the ribbons they are holding down the length of the pole.

**The Moon, Mars, Jupiter, and Saturn were together in Leo in early February as James Westlake shot this with his 55 mm lens. Exposure was 1 second at f/1.7 on 400 ASA film. The rainbow effect is lens flare.**

Of course this also reduces the available lengths of the ribbons, drawing the dancers in closer and closer to the pole — and, not incidentally, to each other.

Finally the ribbons are completely wrapped about the pole, and each dancer finds himself face to face with a member of the opposite sex: now his or her partner for the remainder of the "celebration." Thus the Maypole dance is a sort of giant game of spin-the-bottle, a random process of pairing the young people who take part. Actually, it functioned rather like an ancient computer dating service, for the belief was that rather than being purely random, the pagan god of love and/or sex would so direct the process as to match up suitable couples.

The symbolic sexuality of May also finds a place in the evening sky, for among the constellations visible on May nights are two of the few "female" constellations — Virgo and Coma Berenices (the only others among the 88 are Andromeda and Cassiopeia).

Virgo, the virgin or young woman, is a very ancient constellation which has almost always been identified as feminine. The early Greeks knew her as Kore the maiden, a personification of youth and beauty. To the Babylonians she was Ishtar, the queen of the stars; in Egypt the group was called Isis, chief goddess and wife of Osiris (whom the Egyptians identified with Orion). To the Romans, Virgo was Astraea, the goddess of justice, holding the scales of justice pictured in the neighboring constellation of Libra. In India Virgo was Kanya, the mother of the great god Krishna, while the Chinese see her as a Frigid Maiden (though this is probably due to western influence: the ancient Chinese didn't see a woman in this asterism at all). In the middle ages, Christians easily saw this constellation as a representation of the Blessed Virgin Mary.

But perhaps the most famous association is the one which the later Greeks made, identifying Virgo with Persephone, the daughter of the Earth goddess Demeter (Ceres to the Romans). Hades (or Pluto), the god of the underworld, carried off Persephone to be his wife. Demeter, devastated at the loss of her daughter, struck a bargain with Hades according to which Persephone could spend six months of each year with her mother and the rest with her husband in the world below.

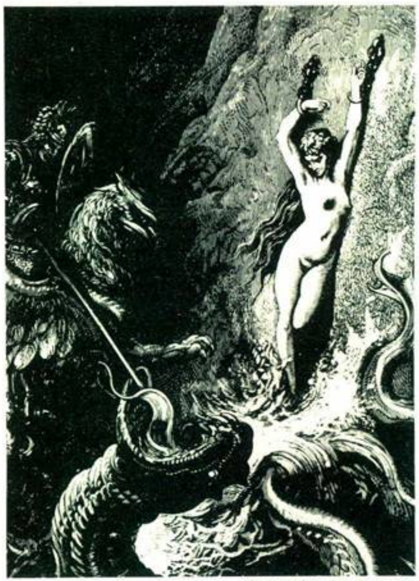

Illustration by G. Dore.

The myth was one of several explanations the Greeks had for the changing of the seasons. When Persephone was with Demeter, Earth was alive and things grew and prospered — in other words, it was spring and summer. But when Persephone returned to Hades, the growing things withered and died, Earth grew cold, and autumn and winter came.

Coma Berenices, the other "female" constellation of spring, is a small, dim figure in comparison to Virgo. But then this asterism represents only a woman's hair, not the whole woman herself. Actually, the constellation is a widespread open cluster.

Coma Berenices received its name as a result of the clever diplomacy of an Egyptian court astronomer in 243 B.C. Berenice, the wife (and, as was traditional in Egypt, the sister) of Euergetes (the third Ptolemaic [Greek] Pharaoh), had placed her hair in a temple of Aphrodite as a thanksgiving offering for her husband's safe return from battle. One day the hair was discovered missing, apparently stolen. Conon the court astronomer, who knew of the glittering web of stars just above Virgo between Bootes and Leo, engaged in some fast talking and managed to convince the queen that Aphrodite had been so pleased with the gift that she had taken it and placed it in the sky as a new constellation.

Samson lost his strength when he lost his hair, but it seems Berenice lost her wits, for she apparently swallowed this hairy tale whole and went away satisfied!

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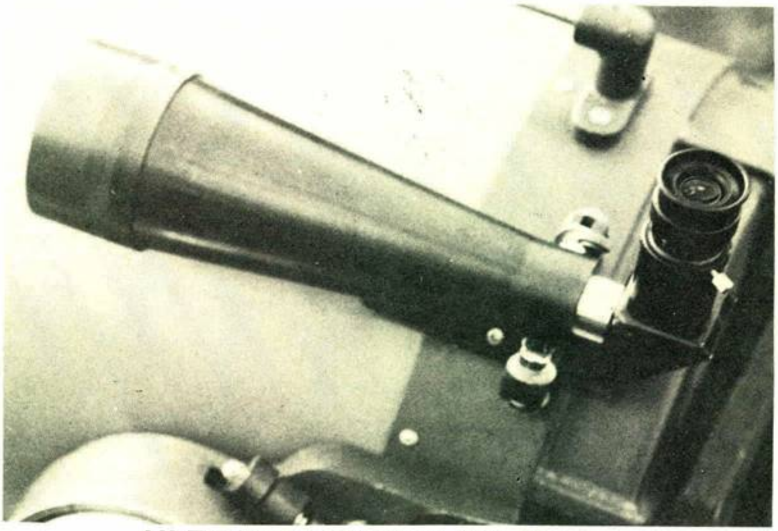

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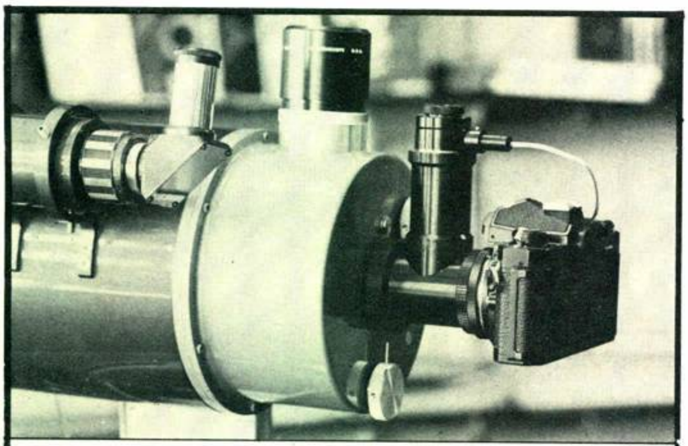

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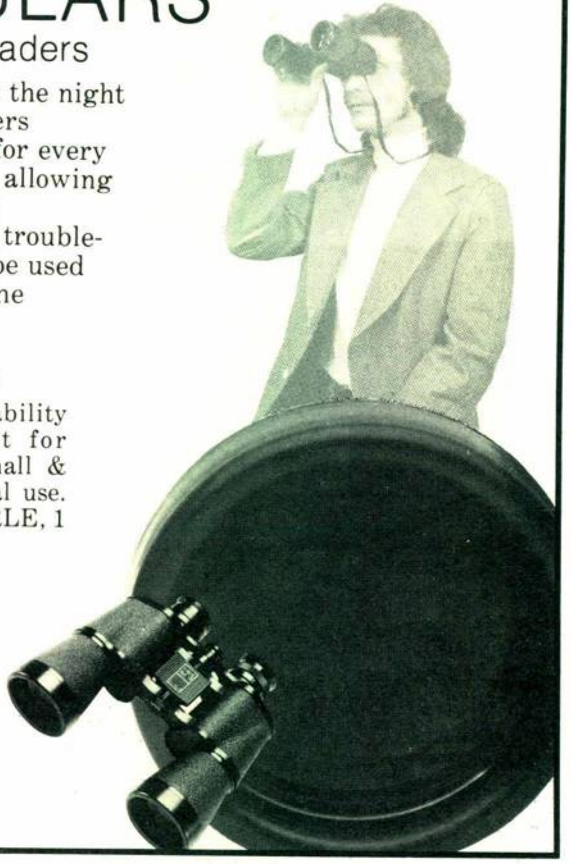
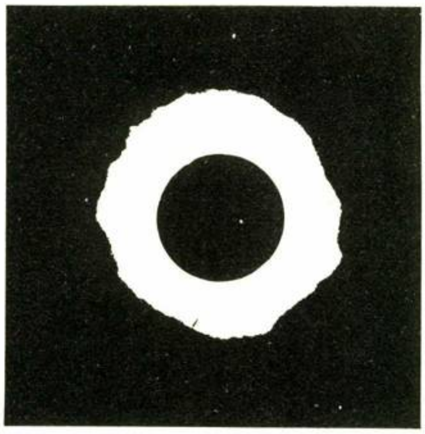




# the afro-indian shadow connection

## by Ben Mayer

The baboons squat close by the reddish dirt road and eye the photographer.

"Be careful," cautions the African guide as he stops the VW Minibus. "Don't lean out of the car so they steal your camera. Me see them do that."

"Click" goes the exposure with the 55 mm lens, to freeze a dozen or so of the enigmatic monkeys in various droll poses. Suddenly, in the middle distance, a giraffe comes into view. In the field of the 500 mm telelens its 18 foot height just fills the frame.

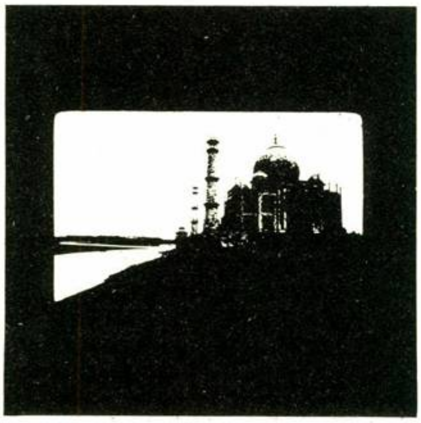
"Giraffe camelopardalis," says the guide, offering the Latin genus. Camelopardalis — hmm, you've heard that word before.

The eclipse is still three days away, but the photography equipment, carried halfway around the world to record it, has been in constant use. It has arrested *wilde*beest and zebra, grazing peacefully side by side. Lazy, half-submerged hippopotami, even ponderous elephants, have filled the viewfinder which may soon see diamond rings. East African crowned cranes with their stiltlike legs have posed in our crosshairs which should soon catch a golden corona.

Coronas and diamond rings — if only the weather will hold. Billowing clouds, lending special beauty to endless windy savannah skies — where elands forage and ostriches prance — dramatize wildlife slides, but bode ill for photographers with hard-to-transport motor driven telescopes.

On Saturday, Eclipse Day, we will see two types of foreign creatures: "long-focal-length pachyderms," people with heavy equipment needing long setup times, and "short-focal-length gazelles," who will be able to outrace the clouds.

They had come from all over the world to witness the impending spectacle and were lining up near the centerline of the eighty-mile wide path of totality. This shadowy corridor will sweep in from the Atlantic, pass over Africa, across the Indian Ocean and India, all the way to China. But along the entire path, the longest duration of darkness will be in Kenya, lying halfway along the shadow's route.



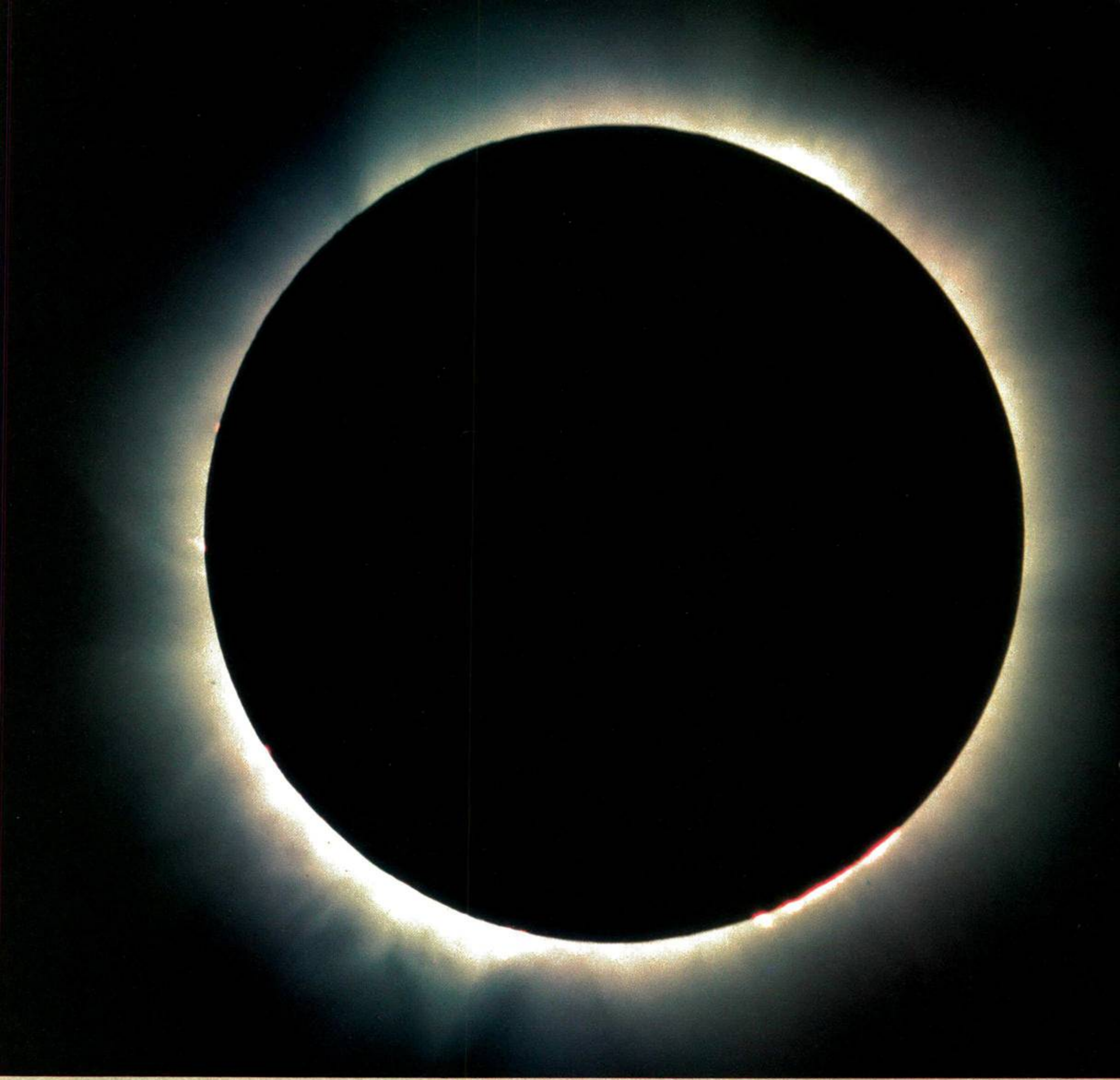
There were Europeans: Germans with precise maps and timetables, Frenchmen conversing with their women in mellifluous tones, Italians declaiming operatically, and the British revisiting lands once theirs, before Kenyatta and Gandhi. Japanese groups had come, even heavier laden with cameras than the Americans.

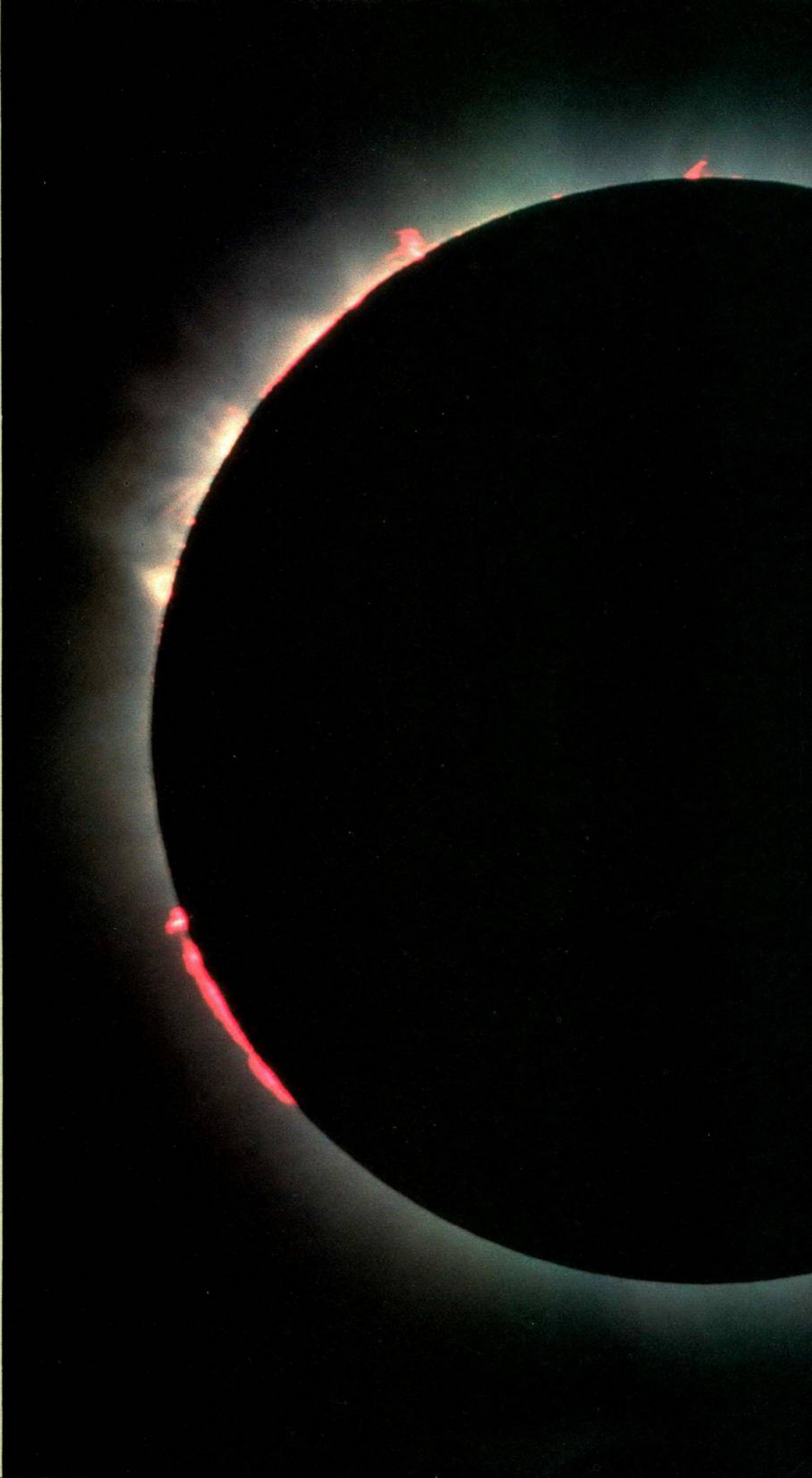
In Kenya, near Voi, the media are represented by Reuters' Nairobi correspondent and those of the Manchester *Guardian*, as well as the Kenyan press. Japan National Television has an entire TV crew on location, a small aircraft at their disposal to carry the team to alternate sites in the event of poor weather. Their Cessna would also transport the eventual videotapes to Mombasa for satellite relay to Japan's evening newscasts.

In Africa, Thursday brings clouds and an afternoon downpour which settles — for a while, at least — the ever-present plumes of dust behind caravans of cars and herds of animals.

Friday, the day before the big event, dawns with layers of mist over the plains, where thick-trunked baobab

**These tangled streamers of gas in the Sun's inner corona attest to the vigorous activity of its atmosphere along the northwest limb. Total solar eclipses provide astronomers with a view of events normally hidden by the blazing glare of light from the Sun's disk. This photograph was taken by William Sterne in Kenya.**



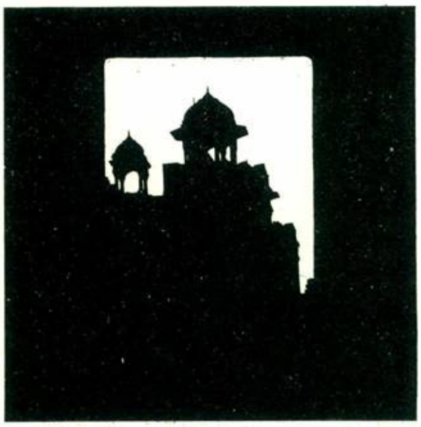


Above: At eclipses near sunspot maximum, the corona always surrounds the blanked-out disk symmetrically (photo by Jacques Guertin). Right: Sandwiched between the inner corona and the Moon are the Sun's ruby-hued prominences — huge outgushings of gas (Jacques Guertin). Near left: Opalescent light filtering through thin cloud circles the eclipsed Sun (Roberta Loeper). Far left: Outer corona in a long exposure (Alex York).

trees will later shade snorting wart hogs and slender topis.

"You must never get out of your car on open road," warns the driver. He embellishes this with tales of motorists threatened by lions while changing tires. "You not see animal in bush, but animal see you."

When, soon afterwards, we saw some lions, first two large males strolling leisurely through the elephant grass and then a whole pride of twenty resting under an acacia tree, they looked at once invincible and supercilious; they knew that hunting has been outlawed and all game they could catch was theirs.



In India, three hours to the east, having viewed the Taj Mahal in Agra and the giant ochre gnomon of the Jantar Mantar Observatory in Delhi, more moonshadow chasers were eyeing the skies, anxious about tomorrow's weather. With no English-language radio or television — let alone satellite weather maps — the small towns and hamlets astride the shadow path could offer no meteorological advice. Far better to follow tradition and seek out a local with roots in the land for guidance:

"Weather will be o.k.," he would vouch.

The scene was set: noble Kenya, with its proud tribes; mysterious India with its structured castes. From Masai warriors' grass huts, to richly carved Hindu shrines; from the giant-tusked, large-eared African elephants roaming wild in the foothills of Kilimanjaro to their domesticated cousins laboring against the backdrop of the distant Himalayas, all was ready by Friday evening.

**Uncanny stillness and sudden gloom: It's very easy to understand the powerful hold solar eclipses must have had on primitive peoples. Even today, the awe you feel as nightfall comes at noon is more than enough to impress the most jaded observer. Photograph by the author.**

For one sizable group of American eclipse addicts in Kenya's Taita Hills, the big day dawned clear and cloudless. On the roof of the famous Salt-Lick Game Lodge and by the pool of the sister lodge nearby, large-aperture telescopes and other apparatus were set up soon after breakfast in anticipation of the 11:20 a.m. event.

Cumulus clouds started forming soon after the Moon had taken its first sizable bite out of the Sun. By 11:00 a.m. the clouds were thick enough to give concern. We anxiously plotted their movement in relation to the blue "holes" between. Only a few observers thought to avail themselves of the African drivers who stood by their "Combis," staring at the rapidly dwindling solar crescent through exposed film or the mylar strips dispensed by the Americans.

But Muchiri, our Kikuyu guide, was ready to drive into the wilderness surrounding our lodge as soon as two of us had hastily stowed our tripods and gear. We chose the eastern dirt road toward Mwatate. Through the open sunroof of the safari-style vehicle, we searched for a site in the fading Sun.

With only two minutes to spare, we skidded to a halt by the roadside, got out, and set up our equipment. Just in time: There now was an oppressive silence all around. No more chirping and rustling in the trees and bushes usually so alive. An ashen light hung eerily over all. Then, totality.

The "dark continent" heightened the drama, and our awe was intensified during the climactic four minutes of totality by knowing full well there were lions and cobras nearby.

"They see you; you don't see them. Two jumps and you finished."

Mechanically, you take your exposures but soon become entranced with the unfolding spectacle.

The darkness of a thousand moonlit nights is distilled by the dampered fires of the blazing Sun into an unearthly noonday twilight.

The seconds fly...

Sadness, joy, and relief mingle when the first glorious rays burst from the precious diamond ring. Totality is over and gone; the glory has left after a few priceless fleeting moments. Yet seeing and feeling the radiance of the Sun restored, you share relief with the thousands of natives who must have watched in dread born of ignorance.

"I will never forget this day," said Muchiri solemnly. "I never see anything like this."

And it will be a long time before another eclipse comes his way again: the next totality here won't be until June 21 in the year 2001.

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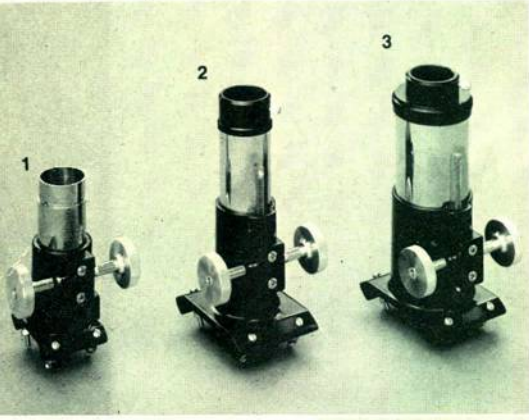

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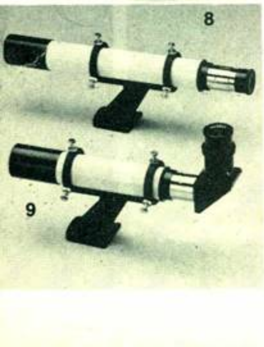

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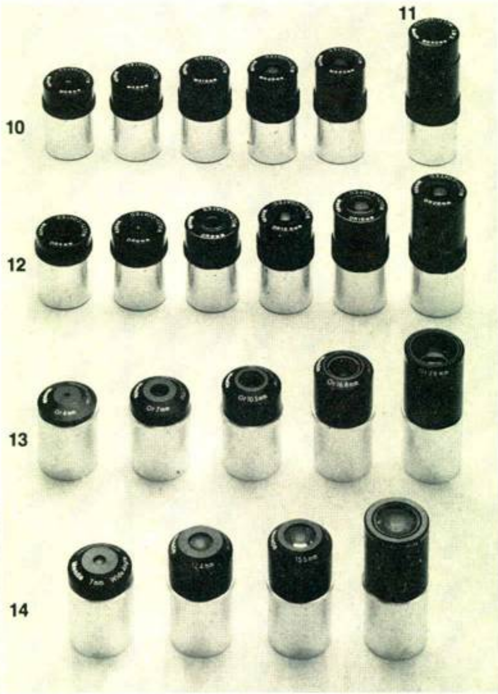

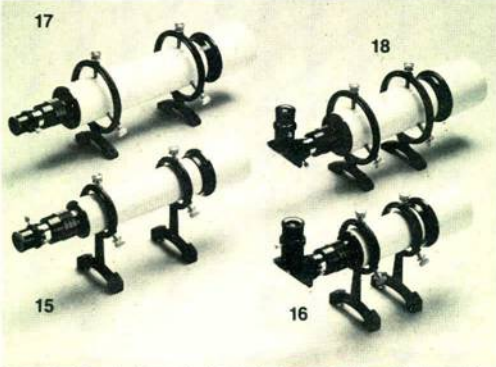

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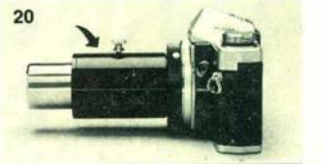
19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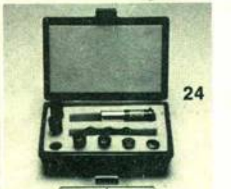
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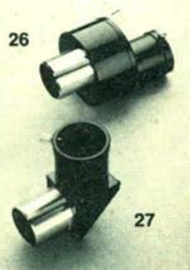

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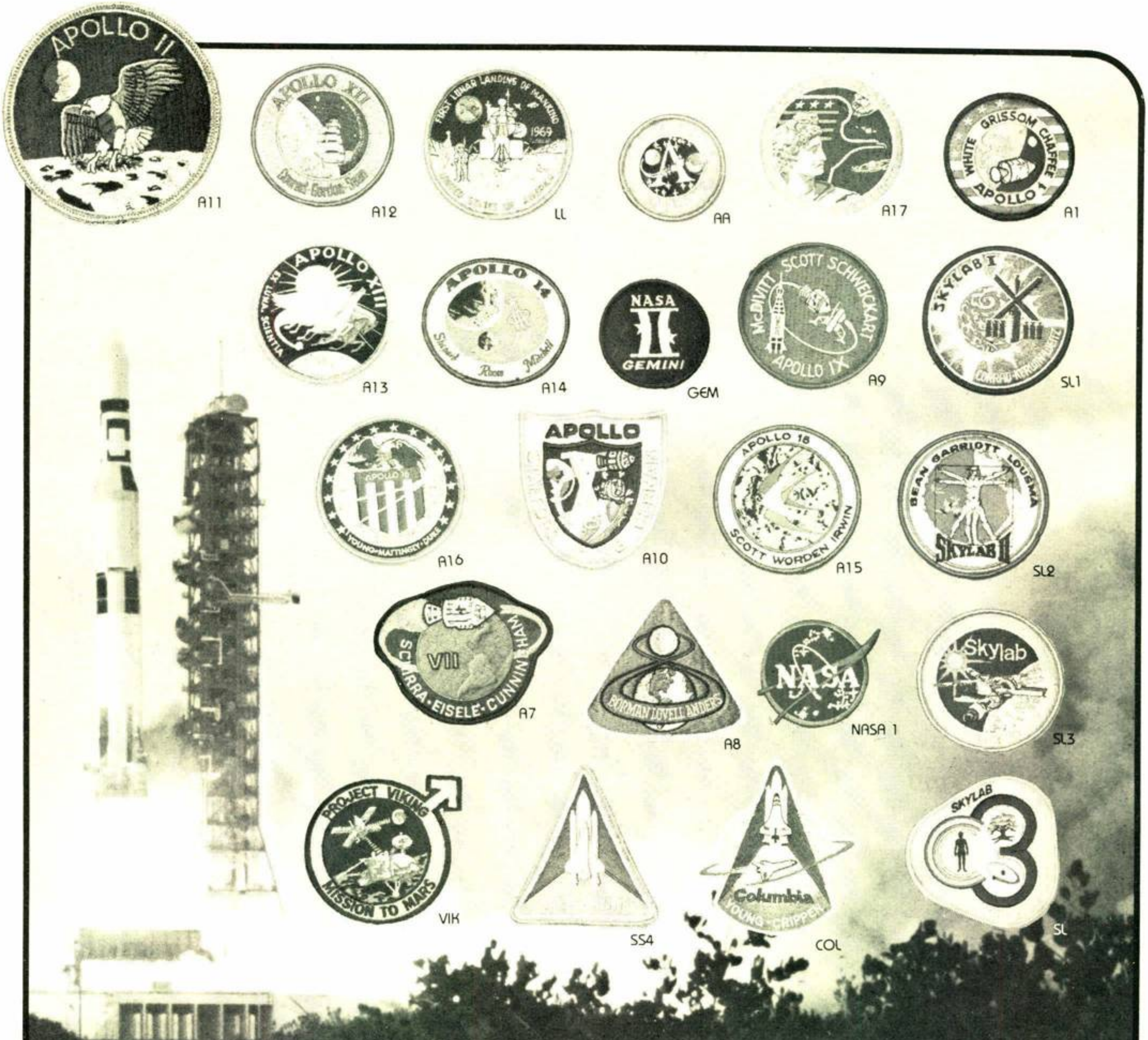

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# an album of galaxies

photography in astronomy

by
Thomas L. Dessert

With the winds of winter gone, we can once more venture out to our telescopes and revel in the mysteries of the spring night skies. The awesome spectacle of distant galaxies speckled across the field of view always leaves me with a very heady feeling. And yet, the view leaves something wanting. Where are the swirling arms, delicate dust lanes and other peculiarities which give these diffuse images their individuality?

There had to be more than was meeting my eye. After all, I had spent too many cold and cloudy nights with my atlases. I knew these features were real, just waiting for me to find the means to see them.

Several years ago while lamenting my observing difficulties, I ran into some stunningly simple revelations. The detail I was seeking is, in fact, detected by my telescope — and present at the eyepiece. However, no human eye would ever see it due to lack of sensitivity.

So close and yet so far! Well, maybe not so far with the right advice and assistance. Fortunately for me, advice and assistance are bountiful commodities in the Buffalo Astronomical Association. From fellow members, I learned that photographic film could "see" all that I desired. Talented club members taught me the fine art of astrophotography. I am still a bit dazed by how fast I progressed. A picture of the Dumbbell Nebula taken on September 22, 1972, although imperfect, will always be very special to me. It was to be the first of many thousands to come in the years ahead. I am occasionally amused by the responses of two sons, who now at 13 and 14 take for granted equipment and results that I, at their age, never dreamed would one day be mine.

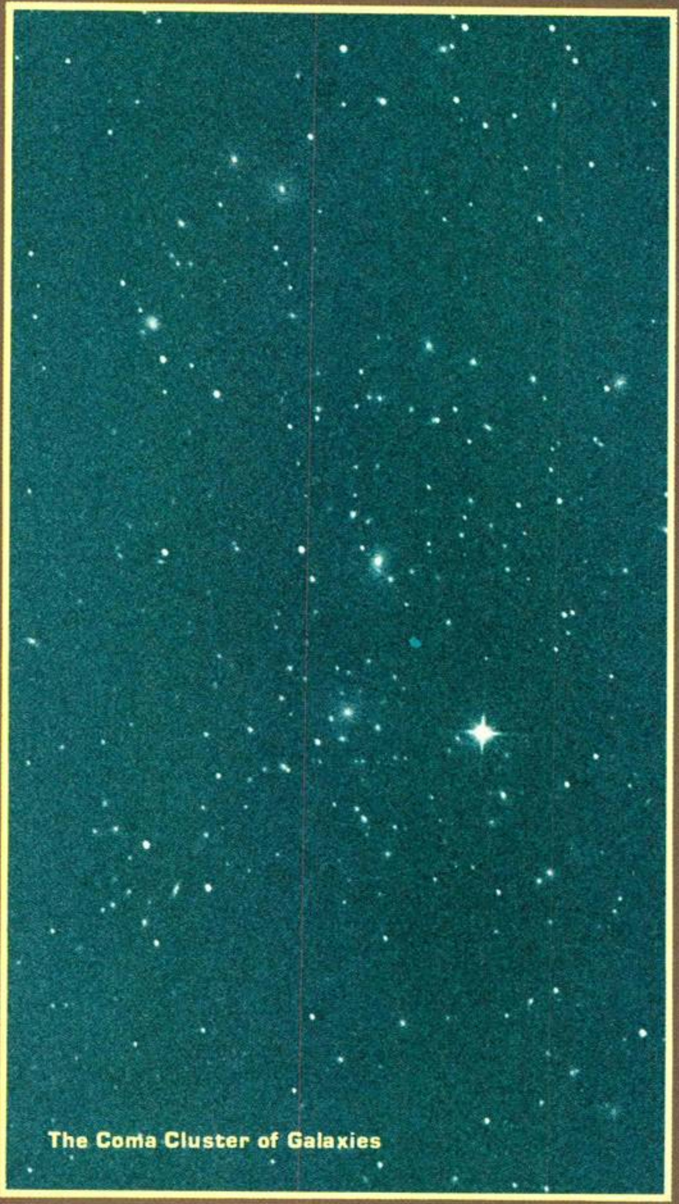
The original commercially made 10" f/6 Newtonian telescope is barely recognizable now in its homemade custom mount and added refinements. A powerful 4" f/10 guide telescope assures that the telescope will track perfectly on galaxies I cannot see. My observatory keeps the chilly Buffalo winds off my back, and my darkroom is a retreat for cloudy nights.

My personal drive and sense of adventure have kept me pushing my equipment to new frontiers. I find that I can photograph stars fainter than magnitude 19. After photographing the entire Messier catalog, my interest returned to the galaxies. I am now bent on photographing every galaxy north of −30° and brighter than 13th magnitude. I have already recorded more than a thousand.

Almost always, the photograph reveals many more objects of interest than originally intended. If each is examined in detail, sooner or later, novae, comets, asteroids, or some unexplainable peculiarity will be discovered. Identifying and cataloging all the nonstellar objects has been, for me, an added bonus. The long cloudy nights of last winter were well spent researching and cataloging earlier photographs.

Where is the imaginative astrophotographer who will one day provide us with the next generation of photographic innovation? Experimenting with new ideas and further development of established concepts have produced the current high state of the art: integration printing, cold-camera techniques, hydrogen hypersensitization, and tri-color compositing, just to name a few.

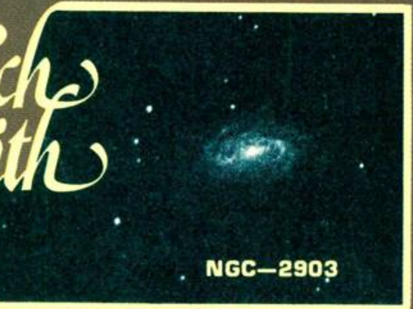
Surely we will not stop now. Do we, for example, transfer all the information from the film emulsion to the print? While computer enhancement is available to the professionals with their budgets, amateur astrophotographers might search for other ways to produce such results. Only by experimenting with new or unusual techniques will new limits and discoveries be achieved.


The Coma Cluster of Galaxies

NGC-4278 NGC-4274

NGC-4631

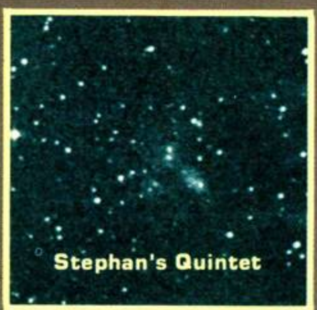
# In touch with The Cosmos

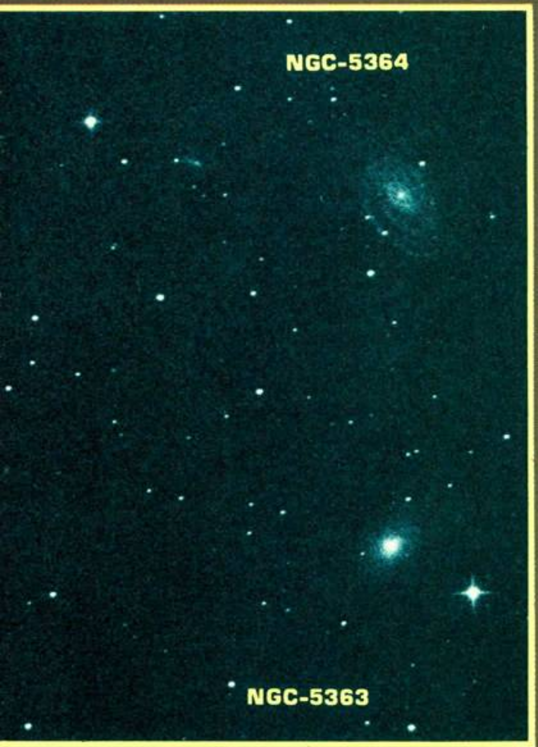

NGC—2903

*The whir of a guide motor, the sound of seconds ticking off the exposure, the image of a galaxy building up delicately on the sensitive emulsion — it's a hobby that puts you in touch with all creation. The photographs on these pages were exposed from 15 to 30 minutes on 35 mm 103a-O or 103a-F spectroscopic emulsions at the focus of Thomas Dessert's 10" f/6 Newtonian reflector.*

NGC-4244

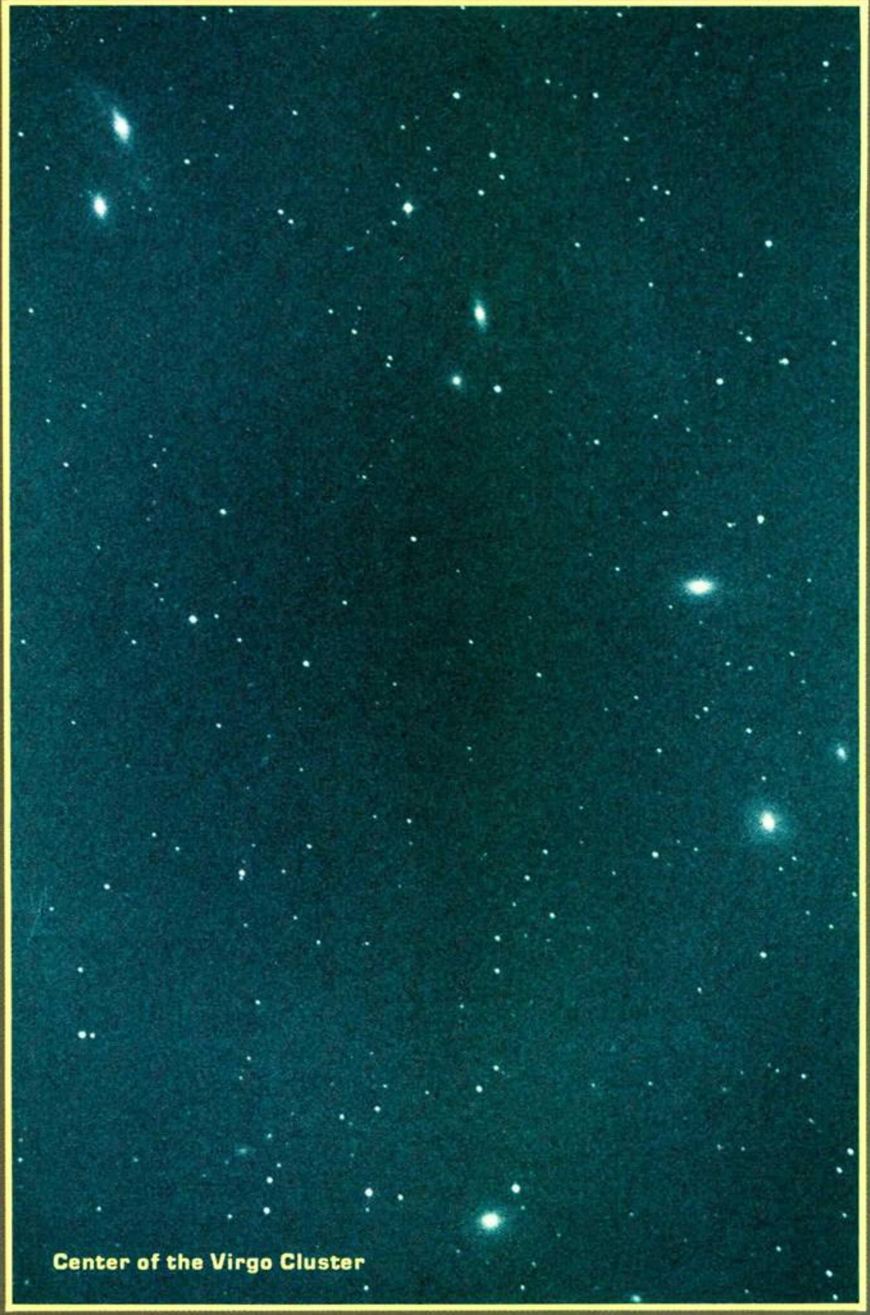
NGC-925


Stephan's Quintet

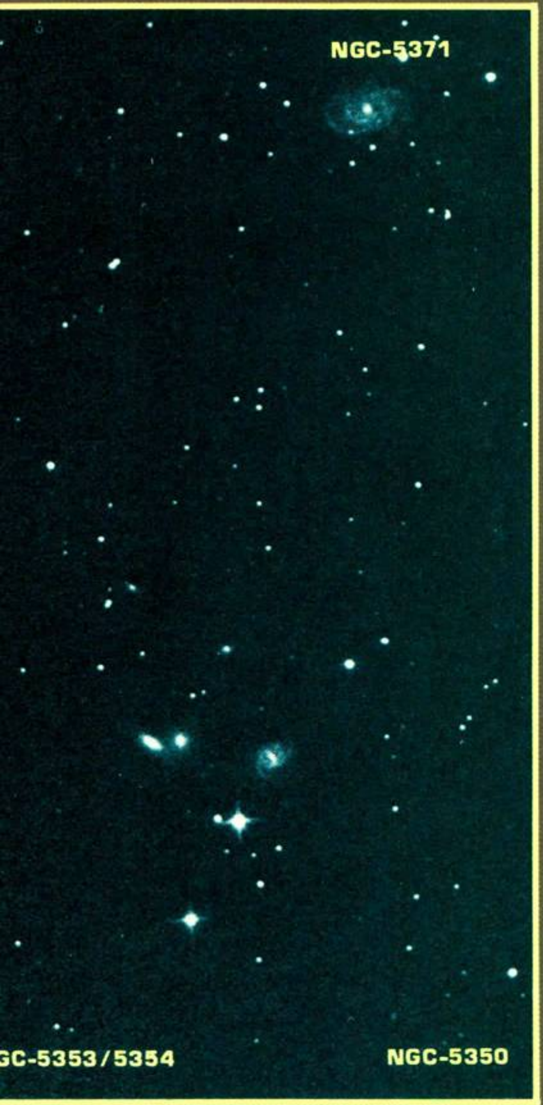


NGC-5364

NGC-5363



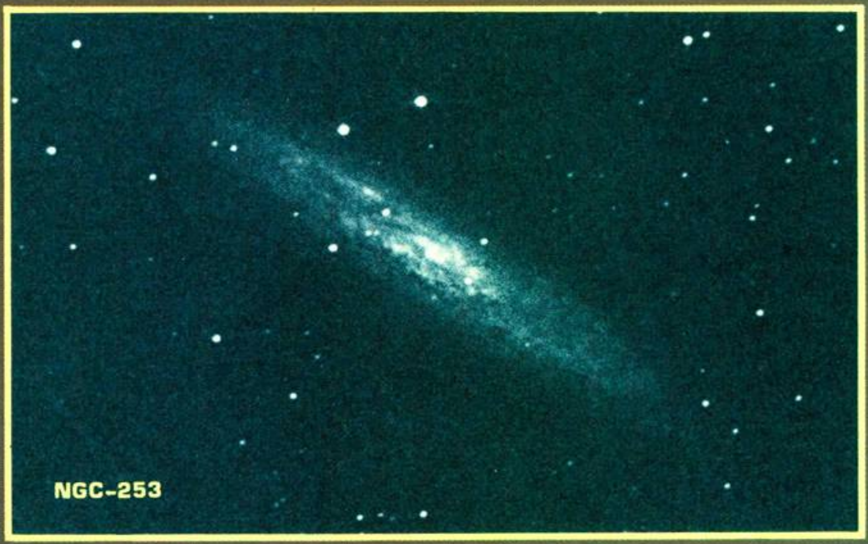
Center of the Virgo Cluster



NGC-5371

GC-5353/5354

NGC-5350



NGC-253

# ASTRONOMY
# IN FOCUS

## Bigger Than a Googol?

Sir / I read with interest the interchange between Mr. Wilton and you concerning googols (In Focus, January 1980). Taking your lead (and without meaning to quibble too much) it seems to follow according to my calculations that at least two quantities surpass the "googol limit": the volume of the universe in cubic nanometers ($2.819 \times 10^{106}$), and in cubic Angstroms ($2.819 \times 10^{109}$).

As for the googolplex: why that, of course, is the number of amateur astronomers one can fit on the head of a pin placed in the umbra of a solar eclipse.

Robb Aley Allan
New York, NY

Sir / I am a charter subscriber to your magazine and read it cover to cover, ads included, as soon as I get it. Last night I read in the In Focus section about the largest noted numbers, the googol and googolplex. It seems to me that in this day when most scientific computing is done on machines that work in base 16, it would be more reasonable to define such numbers in that base rather than base 10. Consider then that a googol is $10_{10^2}$ and a googolplex is $10_{10^{100}}$. The analog to these numbers in hexidecimal (base 16) would be represented in the same fashion since in hex, 16 is represented as 10. But the decimal value of the googol analog would be $16_{16^2}$ or $16^{256}$ and its plex would be $16_{16^{256}}$.

Besides being more convenient for computers, these numbers have the advantage of being much larger than the googol and googolplex and so would provide our grandchildren with the tools needed to calculate the national debt if our politicians continue their present successes in "whipping inflation now and balancing the federal budget." As names for these numbers, I suggest *snootful* and *snootfulplex*, since a snootful is better than a googol any day.

Robert J. Ekstrom
Organ, NM

Sir / My 1963 *Webster's 7th Collegiate Dictionary* defines a googol as $10^{100}$; so far o.k. A googolplex as $10_{10^{100}}$ or $10^{\text{googol}}$. Fine.

But in the same dictionary, under number table in the American System, a centillion is $10^{303}$. The British system describes the same as $10^{600}$. Therefore, it would seem a centillion centillion, or at least 10 to the centillionth is the largest number, or even better, a centillion to the centillionth power ($\text{centillion}^{\text{centillion}}$).

*The Guiness Book of World Records* agrees that centillion is the "highest generally accepted named number." But milli-million ($10^{6,000,000,000}$) is mentioned. Also, Megiston (even larger) "too great to have any physical meaning" is mentioned.

Obviously this can go on forever. However, I doubt a googolplex is the largest number defined, even though I don't know any smaller single 10 letter mouthful (or other larger — for that matter) to express $10^{\text{googol}}$ — unless "megiston" is greater (with only 8 letters!).

H. Gernhardt
Princeton, WV

Sir / It is rare that one is confronted with the opportunity for scientific immortality. However, your response to Richard J. Wilton in the January 1980 issue has provided me with such an opportunity — and I must seize it!

You state that the "largest number defined" is the googolplex. Now, for approximately $10^{\text{googol}} \times 10^{-\text{googol}}$ years, I have been wrestling with the definition of yet a larger number. And I have succeeded!

I call it the "gabboon." Herewith, the definition: A gabboon = $(\text{googol})^{\text{googol}}$.

Now, lest some upstart should seek to outdo me, be aware that I am already feverishly at work on the definition of the gabboonplex!

Can the "galloon" be far behind?

Dale W. Edwards
Hemet, CA

Sir / All right, I want credit for my invention. I'm the inventor of the googolbang, or (googol!). Now that's a hell of a number, and the googolbangplex $(\text{googol!})^{\text{googol!}}$ is a true worthy entity.

Name Withheld by Request

*Editor's note: This correspondence is closed!*

## Write Your Rep

Sir / After reading "A (Sad) Tale of Two Comets" in the February 1980 issue, I was very distressed and disappointed to learn that the Office of Management and Budget has killed the comet project and put the VOIR mission in jeopardy. It is tragic that a project with so much scientific potential can be so callously disregarded.

No doubt that in periods of economic upheaval a good fiscal policy must be tempered with pragmatism; however, one must give long and careful thought especially when it concerns funding for scientific investigation of natural phenomena that may occur only once in a lifetime (e.g., Halley's comet's 76 year period) or only once in many lifetimes (e.g., the "Grand

Tour" planetary alignment every 180 years). Nature can be very difficult to predict at times but when you can, it's usually inexorable.

If we aren't careful, many rare and unique opportunities and much knowledge will be lost for generations. The only way to avoid conflict between the constancy of nature and inconsistant boom-bust economic cycles is a well-defined national goal for the space program.

1980 is an election year and many Congressmen (and women!) from all over the country will be seeking re-election. Listed here are the names of some of the key people in the House and Senate who determine our space policy:
Senate:

Committee on Commerce, Science, and Transportation; Subcommittee Science, Technology, and Space:
Chairman, Stevenson (IL)
Ford (KY)
Long (LA)
Hollings (SC)
Riegle (MI)
Heflin (AL)
Schmitt (NM) — former astronaut
Goldwater (AZ)
Kassebaum (KS)

House of Representatives:
Committee on Science and Technology; Subcommittee Space Science and Applications:
Chairman, Fuqua (NJ)
Flippo (AL)
Watkins (OK)
Bouquard (TN)
Nelson (FL)
Brown (CA)
Winn (KS)
Dornan (CA)
Kramer (CO)

Many of these people are up for re-election this year. I would ask any who believe we should have a strong space program and national goals for space exploration, to write to your Congressmen and Senators to let them know.

"A (Sad) Tale of Two Comets" may be something of a warning to all who believe in the benefits to mankind from space. With budgetary balancing and inflation, the competition for funding in the years to come will be more intense than ever.

Eldridge C. Brunson
Atlanta, GA

### Celestial Beauties

Sir / My interest in astrophotography is only passing, but I must say that I have never in my life seen pictures of such gloriously intense beauty as those I saw in your lead article of the March 1980 issue of ASTRONOMY. For all the technological and astronomical learning this tricolor process requires, these photographs, crisp and pure colorbursts of the heavens, are the most fascinating to me.

My heartfelt thanks to you, David Malin, and the Anglo-Australian Telescope group.

Ken Vander Kooi
Hudsonville, MI

### The Erfles Reply

Sir / We of the Erfle family wish to take exception to your questionable cover query, "What Good Is An Erfle" (January 1980).

We are proud enough to think that we are good at any time whether observing Mars or girls.

Raymond Erfle, Sr.
Philadelphia, PA

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### Ooops...

Thanks to Larry Arbeiter of the University of Chicago Public Information Office for pointing out an error in the names of the researchers who detected isotopic anomalies in cosmic rays ("Cosmic Rays May Come From Supernovae," AstroNews, March 1980). John P. Wefel, a Senior Research Associate in the Enrico Fermi Institute at the University of Chicago, was incorrectly identified as Paul P. Wefel.

behind the scenes

## two new departments

This month, the editors of ASTRONOMY are pleased to present to our readers two "new" departments: **Eye on the Sky** and **Through the Eyepiece**. These new features replace our old standbys Sky Almanac and Star Dome. But we haven't done away with any information: we've simply cleaned house, reorganized, expanded, and renamed them. We've left almost nothing out, and we've put some long-requested data in.

*Eye on the Sky* contains information for naked-eye sky watchers. It's a complete package: it tells you where, and sometimes how, to look for planets and constellations; it contains our new Star Dome map (a veritable country sky in a magazine — it's loaded with stars), plus an indispensable listing of astronomical events we're calling Sky Almanac. Finally, for we wouldn't be without it, *Eye on the Sky* incorporates all the myths, legends, and starlore that you used to find in Star Dome.

*Through the Eyepiece* is geared to the serious observer and astrophotographer. It begins with a detailed planetary section with lots of good information, then moves into descriptions of what to expect when you point your telescope at some of those fascinating deep-sky objects. *Through the Eyepiece* also includes the Constellation Close-Up photographic map. In future issues, we'll be including reports from readers. Don't miss the chance to contribute a report to this section.

For the astrophotographers, *Through the Eyepiece* includes a special place of honor: ASTRONOMY's monthly new "Best Astro-Photo" Award. We've reserved a page opposite the start of *Through the Eyepiece* (page 78 in this issue) for this monthly prize.* And the May winner is: a portrait of the Horsehead Nebula in Orion by California astrophotographer Jack Child.

We're already looking for next month's winner. It could be you. We're searching the photo files and inspecting the pictures that arrive in the daily mail with renewed enthusiasm — looking for that picture that's "got it." It's open — free — to everyone. You don't have to do anything special to win — all photo submissions to ASTRONOMY are automatically eligible.

We're pleased with your — our readers' — response to our new "look" and design. It's been overwhelmingly positive, and it's given us the encouragement to go on making ASTRONOMY the magazine you've told us you want it to be. We hope you'll enjoy the new departments.

Sincerely,

Richard Berry

Richard Berry
Editor

*Oh yes, nearly forgot; winning brings with it a cash honorarium on top of our regular payment.

gazer's gazette

# you're looking in the wrong end, charlie!

As a dedicated astronomy enthusiast, you want to share the joy and excitement of your avocation with others. For their part, those others — friends, relatives, the neighborhood cub scout pack — are all eager to have a look through your telescope.

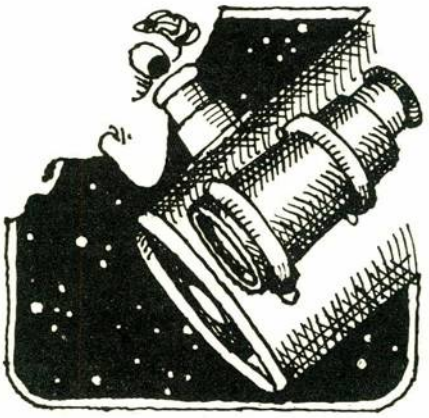
The next scene in this tale finds you standing out in the middle of a dark field with a cub scout hanging from each arm while others clamber all over your prize telescope. One is making faces in the primary mirror, while two others have decided it would make a dandy seesaw. Still another has decided the tripod is a perfect place to play Indians, and is showing a friend how the Indians started fires inside their teepees. The rest are clamoring for a look at the starship Enterprise, or the Death Star, or a black hole. "You promised to show us the far side of the Moon!" one shouts. You have just about decided to give up astronomy for birdwatching, or tiddlywinks, or anything else.

Finally, of course, as you pack up your mangled, smoke-stained telescope, you decide you can enjoy astronomy provided you stick to your new vow never to invite anyone to look through your telescope again. It may be selfish, but, you remind yourself, those "outsiders" never can see anything anyway and if they do, they don't appreciate it.

But wait! Maybe there's a better way. Remember, you were once a neophyte yourself who didn't know which end of a telescope to look in. Maybe you just haven't been approaching these star parties and requests of friends for a look the best way. It's easy to forget that many of the things you take for granted are completely unknown to those cub scouts and your neighbor's cousins. With a little planning, some hard and fast rules, and careful explanation, maybe you'll manage to delight and amaze those cub scouts and your friends and relatives after all!

### Planning the Show

Plan in advance what you're going to show. When do you plan to observe? What's going to be up? Look over a star chart and consult the Star Dome in the current issue of ASTRONOMY to see which objects and planets will be well placed for viewing on the night of the show.



Be sure to pick objects that are not only easy to see through your particular telescope, but ones you are sufficiently familiar with to find them without a great deal of trouble. There's surely nothing more boring for *them* than having to stand around idly in the dark for a half hour as *you* fumble with *your* finder and the slow motion controls, juggling a star chart and an atlas while holding a flashlight in your mouth. It's not particularly dignified, either. So pick objects you know you can find quickly and easily. Resist that request for a look at Pluto.

Oh, yes — you pick the time. Don't let them talk you into a show tonight just because the Moon is full. Invite them back in a week, or better, three weeks. Your friends are going to be much more impressed with the sight of craters on the Moon than anything else you can show them. Plan on having a crescent to gibbous moon in the evening sky — it's a definite plus.

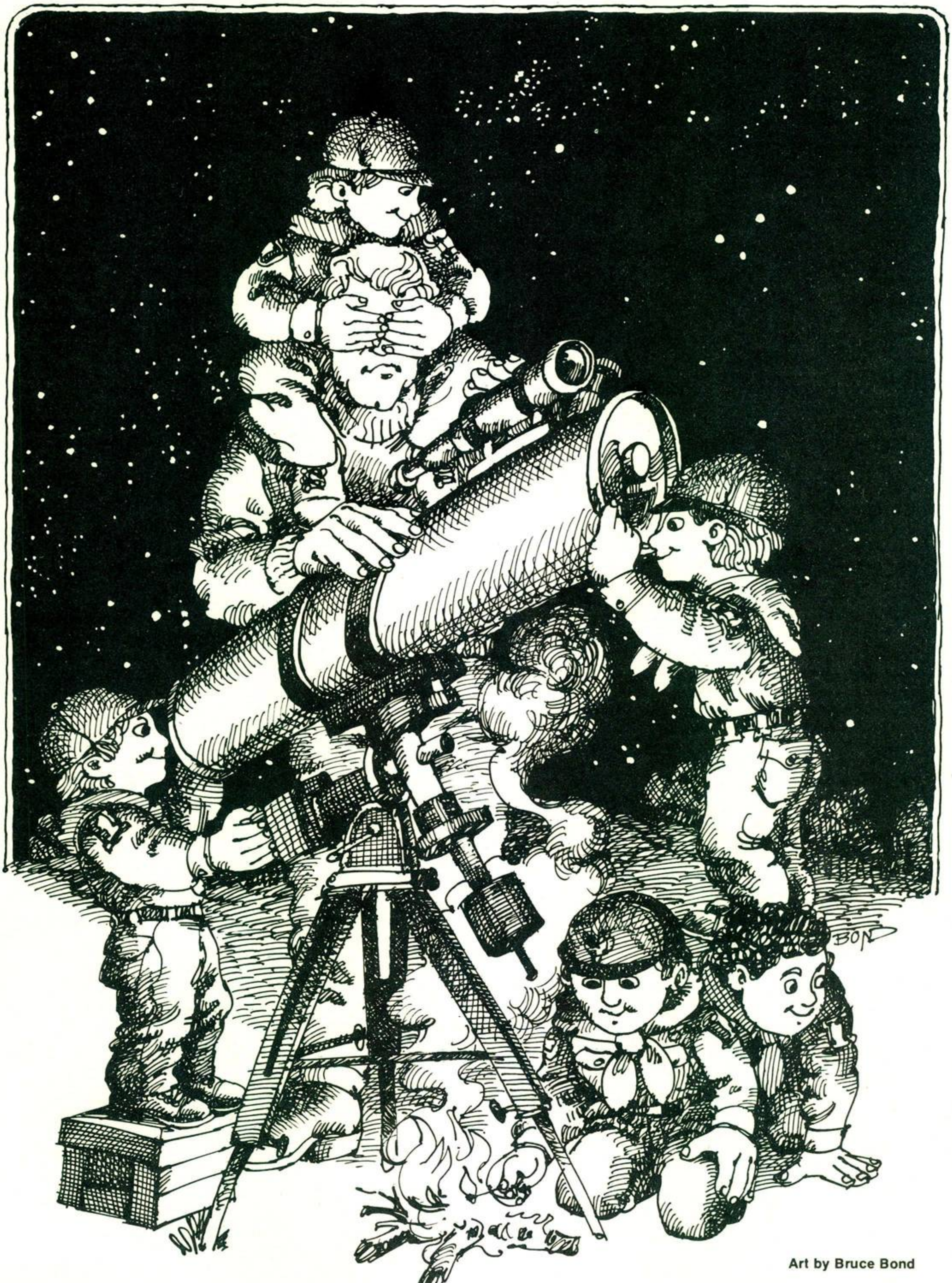
Planets are also good choices, provided you concentrate on the bright and easy Big Four: Venus with its phases, ruddy Mars, Jupiter with its four moons, and Saturn with its rings — when they're visible, that is. Seeing (or rather, *not* seeing) Saturn's rings when they're edge-on (as they are now) may be exciting to you, but that isn't likely to thrill your next-door neighbor's bowling buddy or great-uncle Henry.

As for other objects, keep them few, dramatic, and representative. A cluster here, a diffuse nebula there, perhaps the Ring Nebula and a colorful double star will round out a nice gallery of exhibits. (Most galaxies are for connoisseurs.) Take a look at ASTRONOMY's list of 21 deep-sky objects (October 1979) for a few suggestions — but make sure you can find them, quite literally, in the dark!

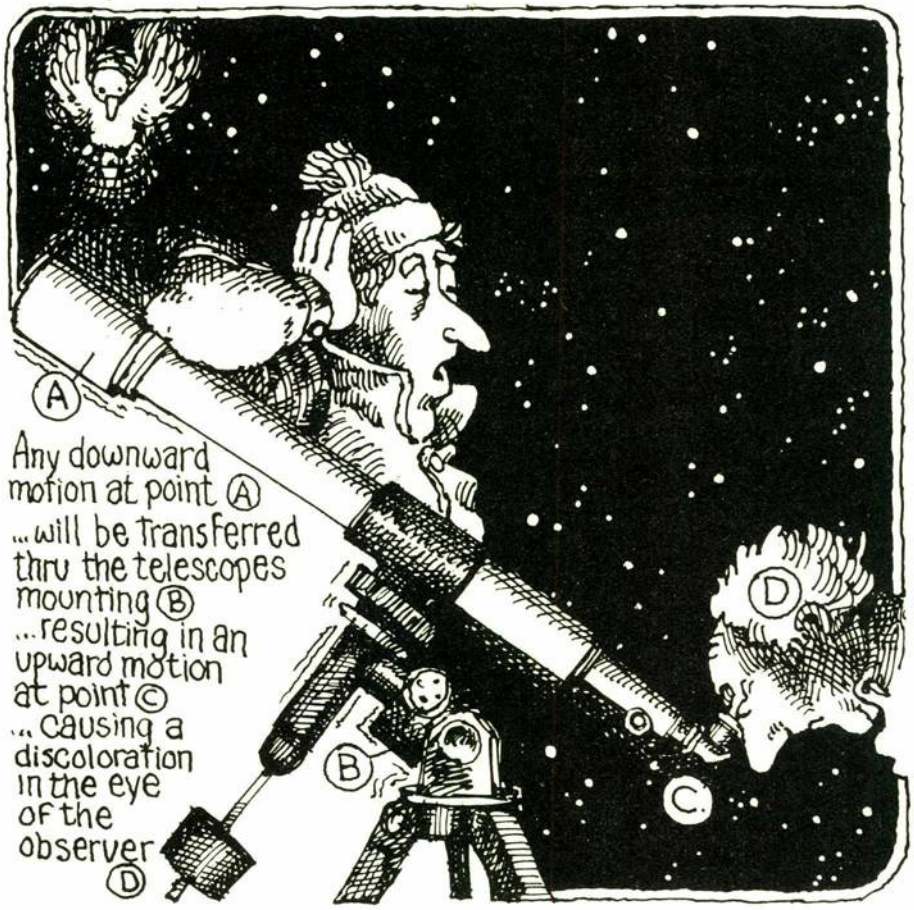
### Setting the Scene

Don't set up your telescope, aim it at some faint object, and tell them to take a look. Give your guests a chance to become dark-adapted first. Talk to them about the sky and give them a little naked-eye tour of things. Point out the most prominent constellations and name some of the brighter stars. Such formations as the Big Dipper, Polaris, the Summer Triangle or the Winter Circle, Orion, and the Pleiades will be interesting sights they can remember and point out to others.

This is also a good time to educate your guests a little about observing the sky through a relatively small telescope. Most people have no idea what celestial objects look like — except for the photographs they have seen taken with large observatory instruments. If they're not prepared, they'll be disappointed at seeing a dim fuzzy blob where they expected to see a dramatic swirling Whirlpool Galaxy



Art by Bruce Bond


Ⓐ
Any downward motion at point Ⓐ
...will be transferred thru the telescopes mounting Ⓑ
...resulting in an upward motion at point Ⓒ
...causing a discoloration in the eye of the observer Ⓓ
Ⓑ
Ⓒ
Ⓓ

or vivid colored streamers. Explain that the excitement comes from a knowledge of the nature of the object you're viewing and the realization that you're actually looking at the object itself firsthand. They'll be impressed you could find it in the first place! Suggest they see how much detail they can pick out at your eyepiece. Just whisper, "It's the real thing!"

Remind them of this again when they are viewing. Point out, for example, when they are looking at the glow of the great galaxy M-31 in Andromeda, that the light entering their eyes comes directly from billions upon billions of stars over 2 million light-years away, and that the light has been on its way to Earth for over 2 million years just to end up right there on their retina. If that doesn't elicit a "wow!" from your second cousin, he or she is probably just the kind of person who likes to litter the roadsides and stomp on roses now and then.

### Showing Off the Sights

With your guests dark-adapted, the telescope set up and aligned, the drive on (if you have one — if you don't, better stick to the lowest magnification you have and the brightest objects you can find), you're ready to go.

You center Jupiter in the field of view, find all four satellites nicely arranged alongside it, and the belts (along with the Red Spot as a bonus) are clearly visible. You step back and, having carefully warned everyone not to touch, kick, or otherwise molest the telescope in any way, invite the first observer. He steps up to the eyepiece, removes a pair of glasses, squints tightly and covers one eye with a hand, leans over and promptly drives the eyepiece about a quarter of an inch into his eye socket.

When you have finally centered Jupiter in the field of view once again and your friend has stopped moaning and clutching his smarting eye, he bravely (but gingerly) tries again, only to announce that all he sees is a bright blob. "You have to focus it," you say. His hand moves to the focusing knob.

For the third time you center Jupiter in the eyepiece, and, telling him to keep his glasses on this time, say, "There! Try it now...." A white blob again. What belts? What Red Spot? What moons?

You've made a number of mistakes already. Most people are awed by strange machines. Don't frighten them off. Let them know they can't harm it. Then use a low power eyepiece that's easy to look through. Make it easy for both them *and* you. Advise your guests who wear glasses to keep them on when observing. (Not only does that eliminate most of the problem with correct focusing, but also their eyes will be protected from the unwelcome intrusion of the eyepiece!) Those who don't wear glasses should be told to keep their eyes a respectful half to quarter-inch from the eyepiece. Show them how to focus if they have to — "Here's how to make the picture clear. Just turn this knob." Remind them they don't have to squint or cover their other eye. Just relax and look straight in with their eyes wide open.

And don't leave them alone to look uncomprehendingly at strange things, especially when showing deep-sky objects such as planetary nebulae and diffuse nebulae. Take the opportunity to tell them something about the nature of the object they are looking at and why it's interesting. Promise them pictures later so they can "see" what they saw.

If you have more than a couple of people present, have a pair of binoculars on hand to pass around for those waiting their chance at the eyepiece. If the Milky Way is well placed in the sky, tell the others to simply scan along it with the binoculars and see what they can see. If you've got a second telescope, particularly if it's a richest field telescope, that can be an excellent second attraction just left aimed at a particularly rich star field or something like the Pleiades.

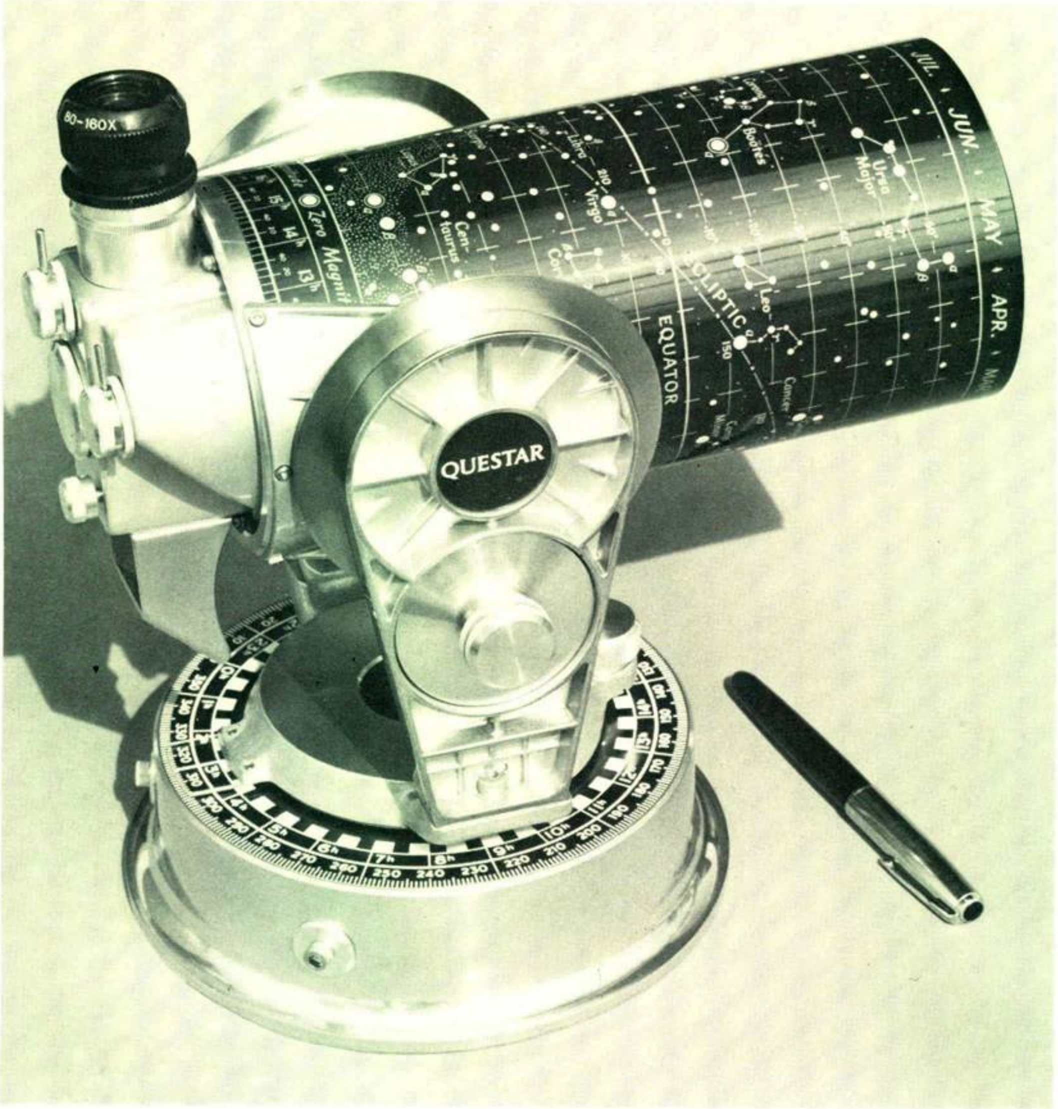
And another thing, deep-sky objects *are* hard to see. When you first started, you had your troubles — now it's their turn.

Averted vision is a technique that is easy to teach. Tell your guests that they can see those dim fuzzies provided they don't look at them. Pause and relish for a moment the puzzled looks you'll get. Then, having explained that the area of the retina away from the center of vision is actually much more sensitive, instruct them to look to the side of the field. They won't be able to see as much detail as you can — experienced observer that you are — but they'll see the object.

If the Moon is on the evening's agenda, save it for last. What your guests are most likely to remember about the evening are those fantastic views of lunar craters, mountains, and plains. On the other hand, maybe you'll want to show it off first — especially if it's setting. That will get them interested, and they'll want to see more.

Who knows? One of them may want to get together again to try to see more jovian detail, or to search out some galaxies when the Moon is absent. You may discover you've inspired an enthusiasm for astronomy in someone, and the next thing you know all your back issues of ASTRONOMY will be out on loan and you'll be asked for advice on the best telescope to buy!

— *Dewey Schwartzenburg*



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# ASTRONOMY REVIEWS

**The Rocket Team**
Frederick I. Ordway III
and Mitchell R. Sharpe
462 pages, hardcover, $14.95
Thomas Y. Crowell Publishers (1979)

In May 1945 a small group of Germans waited at Haus Ingeburg, an inn near Oberjoch, Germany, for the return of Magnus von Braun. His mission had been to approach the American military authorities of the 44th Infantry Division with a surrender offer from a hundred German rocket scientists and engineers under the leadership of his older brother, Wernher von Braun. The subsequent surrender of the developers of the V1 and V2 vengeance weapons closed a chapter of history which saw these men mold the rocket into the most advanced offensive weapon of World War II. At the same time, another chapter was begun. These same men who were considered by some people to be war criminals would later be recognized as pioneers in the new science of liquid rocket research and space exploration. Frederick I. Ordway III and Mitchell R. Sharpe deal with both halves of this story in their book, *The Rocket Team*.

Ordway and Sharpe organize their tale with a chronology of events, bringing each actor into his role as his portion of the story is told. The authors draw upon personal experiences, having worked with many of the people depicted in their book. Ordway worked with Wernher von Braun at the NASA Marshall Space Flight Center near Huntsville, Alabama. Sharpe has authored many books on space flight and has been identified with the space program for over twenty years. Both men interviewed many of the Germans, including von Braun, whose influence is evident throughout the book. Direct quotations and a foreword written by the "Professor" just nine months before his death provide insight into the life of this controversial engineer. Photographs of von Braun and other members of the German team, as well as action photographs of their creations are dispersed throughout the book.

*The Rocket Team* covers the time span from the late Weimar Republic in Germany to the Apollo moon landings of the 1970s. Hermann Oberth organized an enthusiastic group of amateur experimenters into the Verein für Raumschiffahrt (Society for Space Travel) in 1927. Two years later nineteen-year-old Wernher von Braun joined the VfR.

The VfR and von Braun grew up together. In 1932 Wehrmacht Captain Walter Dornberger solicited the skills of the VfR to build a "Repulsor" rocket for demonstration launches at the army's proving ground at Kummersdorf. Even though this particular demonstration was a failure, Dornberger was favorably impressed by von Braun's talents as an engineer and organizer. In the years to come, von Braun and Dornberger would face financial and political obstacles as they attempted to prove the worth of the rocket as an offensive weapon to the leadership of the Third Reich. By 1939, the original group of 870 VfR members had grown into 1960 scientists and technicians, and were employed by the Heersversuchsstelle Peenemünde (Army Research Center Peenemünde) to develop the Vengeance or "V" rockets. Over 6000 V2 and 30,000 V1 rockets were built before Germany's collapse in 1945. Of those weapons manufactured, 24,000 were successfully launched against the military and civilian populations of the United Kingdom, Belgium, and France.

The authors point out how the Peenemünde group had survived British bomber attacks, and harassment by the SS, but the group could not defend themselves from the invading Russian army. On February 17, 1945 von Braun ordered the evacuation of Peenemünde. He disregarded Hitler's "scorched earth policy" and buried all pertinent data and reports in an abandoned mine near Dörnten, Germany. In May 1945 most of the German engineers followed von Braun and offered their services to the United States Army. The remaining engineers and technicians followed Helmut Gröttrup to the Russian side. Both groups influenced their captors' futures in weapon research and space exploration.

Von Braun's Germans confronted many old familiar problems during the postwar days. The rocket's capabilities as a weapon had been proven during World War II, but its potential as a scientific tool had not been fully explored. It was not until Helmut Gröttrup's group in the Soviet Union launched the first satellite (Sputnik) that the American military realized they were second in the conquest of space. The Germans in America quickly made up for lost time. By 1969, they realized a forty-year-old dream of sending a man to the Moon.

Ordway and Sharpe's treatment of the postwar years is not as detailed as their description of the years the engineers spent under Nazi control. Only four of the nineteen chapters in the book deal directly with the Germans working for the Soviet Union and the United States. The last chapter covers most of the research in space travel and exploration. In this respect *The Rocket Team* is not as complete in its handling of the technical side of the story as it is with the personal. The epilogue summarizes what has happened to the Germans; most of the team in the United States is depicted as being forced into premature retirement by officials at NASA headquarters.

*The Rocket Team* tells the story of how a small group of German engineers restructured the course of rocket development from a weapon of the Nazi regime into a tool of science. As a history reference, this book provides interesting and factual reading on one of the most influential technical achievements of the twentieth century. *Jerry L. Borrer.*

**Theoretical Cosmology**
A.K. Raychaudhuri
298 pages, hardcover, $26.50
Oxford University Press (1979)

The issues debated in modern cosmology are fascinating to nearly everyone, but this book, while being a complete survey of the most significant modern issues, is most definitely not for everyone. A highly technical and mathematical treatment for advanced graduate students and physicists, the work assumes familiarity with tensor and scalar calculus and the other advanced mathematical tools of modern cosmology.

The author does not limit his discussion to the classic General Theory of Relativity. Competing models for gravitation, such as the Brans-Dicke, Hoyle-Narlikar, and Einstein-Cartan theories, are also considered. Nor is the discussion purely theoretical, despite the book's title. Several chapters and portions of chapters deal with observational data, such as an excellent one titled "The Microwave Radiation Background." An extensive list of references, fairly complete through 1977 and including some later studies, is a valuable addition.

One can only regret, though, that the prestigious Clarendon Press at Oxford University has resorted to printing finely-bound and well-printed volumes such as this one in typewriter script rather than typeset copy. Has the Clarendon Press sunk so low? *Dewey Schwartzenburg.*

**Broca's Brain**
Carl Sagan
347 pages, hardcover, $12.95
Random House (1979)

Carl Sagan is a superb writer: witty, controlled, smooth, and in complete command of the English language. In this collection of essays, Sagan rambles through diverse fields of science, effusing over the many pretty pebbles he finds on the way. He discusses robots and artificial intelligence, Titan, the asteroids and the chunks of them that may have reached the Earth; he has written a delightful essay on turn-of-the-century American astronomy, the life of Robert Goddard, and science fiction.

Sagan also mounts several attacks on various modes of pseudoscience — spiritualism, the Dogons as a tribe visited by ancient astronauts, Velikovskyanism (complete with ten problem areas and four supporting appendices), as well as Biblical crackpot Norman Bloom — which come off harsh and sniping. In contrast, the title piece, "Broca's Brain," is a splendid reflection ("Alas, poor Broca, I knew him well!") on the nature of mind as Sagan stands, brain bottle in hand, deep in the dusty storeroom of the Musee de l'Homme in Paris.

In his last essay, "The Amniotic Universe," Sagan indulges in an extended speculation, loosely linking out-of-body experiences, birth, psychedelic drug trips, ancient religions, cosmological wonder, and man's leavetaking into space. This makes for good reading, but perhaps it deserves some of the critical scrutiny that he wielded on Velikovsky.

The volume is united primarily through its subtitle: "Reflections of the Romance of Science," for common to all the essays is an appreciation of scientific thought. But as romance, science is rather dry — even when described by Carl Sagan. More wondrous than his list of scientific wonders, more romantic than the marvels of Mars or of DNA, is the nature of science itself: "science is more intricate and subtle, revealing a much richer universe, and powerfully evokes our sense of wonder. And it has the additional and important virtue... of being true." *Richard Berry.*

**The Realm of the Terrestrial Planets**
Zdenek Kopal
223 pages, hardcover, $19.95
John Wiley (1979)

Kopal, the author of many professional and popular scientific books, has written a survey of the solar system from the asteroids inward. He integrates the results from the Apollo, Mariner, and Viking missions; the presentation is at about the Stellar Frontiers level.

**The Master of Light: a biography of Albert A. Michelson**
Dorothy Michelson Livingston
376 pages, paperback, $6.95
University of Chicago (1979)

Though he never thought of himself as other than a physicist, Michelson made discoveries in optics which have singular value to astronomers. His stellar interferometer allowed them to measure directly the sizes of some of the nearest giant stars, and a corollary technique used with radio telescopes provides fine angular resolution. He also determined very precisely the speed of light.

But far more important than this was the classic experiment that Michelson ran with Edward Morley, the results of which led straight to relativity. The author of this engaging and informal book is Michelson's daughter, and while she provides an adequate summary of the scientific work, the biography's greatest value may well be its protrayal of the very human being behind the stiffly formal exterior.

**Is There Life in Outer Space?**
Alexander Langadas
82 pages, paperback, no price given
Published by the author (1976)
[order from A. Langadas, Beles 24, Athens 401, Greece]

Mr. Langadas, a Greek science writer, has written a book examining the question stated in his title. About half the book discusses the conditions and prospects for life in the solar system; the rest of it does the same, with more speculation, for the Galaxy and beyond. His last chapter demolishes the von Daniken silliness.

**Astrophysical Formulae**
Kenneth R. Lang
735 pages, paperback, $29.50
Springer-Verlag (1978)

Bristling with Greek letters, integral signs, numbers, and exponentials, Lang's *Formulae* (now out in paperback) is a standard on the shelves of most astrophysicists, for it contains nearly every basic formula of importance.

**Space Shots**
Fred Hapgood
79 pages (illus.), paperback, $7.95
Times Books (1979)

Subtitled "an album of the universe," this large (9" x 12") book is just that: a pictorial tour of celestial objects. There are 19 chapters, generally one per object or class of objects (Earth, Sun, Mars, supernovae, etc.) and the ratio of text to pictures is about 1 to 3. Most of the photos are in color, and the introduction is by Michael Collins.

**Shuttle to the Next Space Age**
David Dooling, ed.
131 pages, paperback, $18
Am. Inst. Aeron. & Astron. (1979)

In 22 chapters and 2 appendices, many experts in the field of space development discuss how they expect the Shuttle to be put to use.

# AstroNews

## U.S. Lagging in Space Exploration and Technology

The nation faces a gap in planetary exploration unless funds are made available to start new programs soon, according to two top NASA officials. And a report issued by the General Accounting Office, the congressional investigative agency, claims that the United States is in danger of losing its lead in space technology.

Dr. Robert Frosch, NASA administrator, and Dr. Thomas Mutch, associate administrator for space science, gave their warnings in congressional testimony and an interview.

"Since it can take between five and ten years from the start of a project to the return of data," Frosch told the House science and technology committee on January 29, "now is the time to be thoughtful and precise about future mission planning. An exciting and vigorous program can still be sustained, by capitalizing on our investment to date. If we affirm our strategy of exploration — that is, progressing systematically from a level of reconnaissance through exploration to detailed study of the bodies in our solar system — clear goals emerge."

"We look forward to this decade, with its rich potential. We continue to plan for future planetary exploration and for enabling technology," Dr. Frosch concluded.

Planning, though, may be much of what NASA does if "new start" funds are not made available for more programs. The proposed fiscal 1981 budget, on which Frosch was giving the committee an overview, has no such money: it was refused by the Office of Management and Budget which makes all federal budgets. Permission was sought for two planetary missions, the International Comet Mission to Halley's and Tempel 2, and the Venus Orbiting Imaging Radar (VOIR).

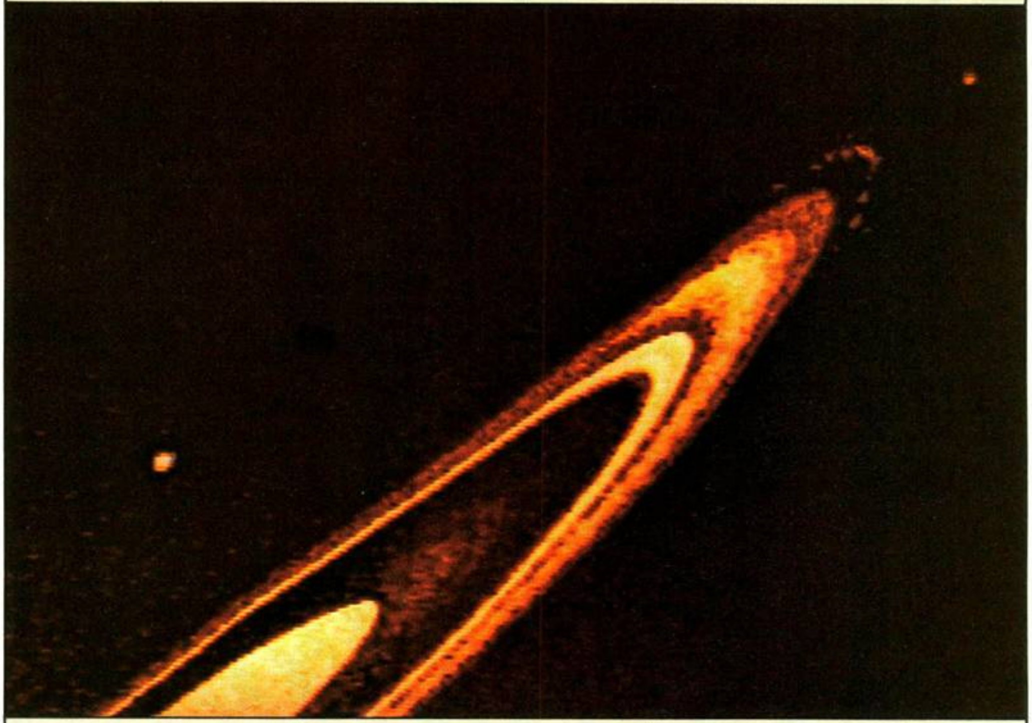
At present, NASA has four major planetary projects underway: Pioneer Venus Orbiter, Viking (one orbiter and two landers), Voyagers 1 and 2 (now en route to Saturn), and Galileo orbiter and probe to Jupiter (set for launch in 1984).

"Last year was the year of the planets," Mutch said in an interview, "and given this bonanza, the layman might well ask, 'What cause do you have for concern?'"

"Well, you plan missions so far in advance that you really have to have tremendous foresight. And what's happening here in 1980 does not directly suggest what is going to happen in the 1980s. A high-priority mission, for example, will not be returning data until the 1990s. And it is this sort of hiatus that has alarmed many people."

Thus, the spectacular images of Jupiter and its moons sent back by Voyagers 1 and 2, and the first close glimpse of Saturn

## *The Best View Yet of Saturn's Rings*



*This computer processed and enhanced picture of Saturn's rings, taken by Pioneer 11 on August 31, 1979, shows structure and detail never before seen. Beyond the outer tip of the A ring (the outer visible ring) can be seen, for the first time, the thin band of the newly discovered F ring, and just beyond this is the image of Saturn's newly found 11th moon, 1979 S-1. The satellite Tethys is seen at left just above the rings. The spacecraft viewed the rings from the north side, the side not lit by the Sun. However, as sunlight comes in under the rings, it is reflected from ring particles and passes through the rings. This view of sunlight through the rings allows assessment of the thicknesses of ring material. The new outermost F ring is less than 310 miles in width. It is separated from the outer edge of the outermost visible ring (the A ring) by a gap of about 2240 miles, known as the Pioneer Division in honor of the spacecraft. Pioneer's measurements of ring mass showed the A and B rings to have a very low density, indicating that they are largely ices rather than denser materials. The outer A ring was known to be divided into the two sections seen here, but the light and dark features it contains are new. The outer quarter of the outer A ring is substantially darker than the rest of the ring. The inner part of the ring shows several areas of lower density, and the ring's inner edge is very dense, as opaque as Saturn's crowded B ring. Also new is the extreme brightness of Cassini's Division, showing that it contains substantial amounts of light scattering material. The dark feature in Cassini's Division is also new. The rings are very thin, with estimates of thickness ranging from several meters to as much as three kilometers (two miles). The orbiting ring particles probably range from snowball-sized to automobile-sized pieces with a few having a diameter of a mile or more. NASA photograph.*

via Pioneer 11 (to be followed by the Voyagers), could well be the high marks of interplanetary exploration this decade until Galileo arrives at Jupiter.

An additional problem is that as new missions are deferred, they stack up in the pipeline, as planetary director Angelo Gustaferro said. Unless funding is uncorked soon, there will be more missions than even an expanded budget could handle.

"Our inventory of possible planetary missions is not all that large," Mutch said. "We're not asking for an extravagant amount of goodies."

In addition to the scientific need to explore the planets, Mutch said, there is also the emotional need, one never included in the budget calculations.

"I think it is undeniable that the exploratory excitement is greatest when people are looking at objects they can easily relate to," he said. "Like the extraordinary empathy we developed with the whole world for Mars...and the knowledge that there was this real place out there on the surface of another planet is a profound idea, difficult to verbalize, but there."

In a related development, the report issued by the General Accounting Office stated that "It is evident the United States has reached a point where it must decide on the importance of retaining worldwide technological leadership in space."

The agency pointed out that a number of countries, including the Soviet Union, Japan, and several Western European countries, are devoting strong efforts to research in the field of space manufacturing. Such research could lead to substantial commercial and economic payoffs.

In order to maintain equality with other nations in this field, the United States should be spending two to three times the $20 million currently budgeted by NASA for such research, according to the report.

"There is concern in this country that once the space shuttle and Spacelab are in operation, emphasis by other countries could lead to technological and economic advantages which may be difficult to overcome," the GAO report said. "Many industrialists and economists believe that being 'first to market' with new products or processes is extremely important in gaining a large enough market share to remain competitive."

The weightless vacuum of outer space could make a number of industrial and manufacturing processes easier and more economical. Yet the United States has scheduled only 14 experiments in materials processing for Space Shuttle testing, only 9 of which have been assigned to specific flights so far. In contrast, the 11 European nations are committed to a total of 39 such experiments on the first Spacelab mission alone.

"It is evident the United States...must decide on the importance of retaining worldwide technological leadership in space," the G.A.O report said.

The report called for a larger measure of participation in space technology and industrialization on the part of private industry. "Enough of the right kinds of research in [a weightless outer space] environment," the G.A.O. report said, "could create a virtual knowledge explosion."

## Index

- U.S. Lagging in Space Exploration and Technology
- The Best View Yet of Saturn's Rings
- Antarctic Meteorites and Life
- The Elements in Old Stars
- The Physics of Distant Stars
- Hector *is* a Strange Asteroid
- Orbit and Climate
- Jupiter's Weather

# Antarctic Meteorites and Life

A NASA meteorite sample program is providing basic clues to a University of Maryland researcher in the quest for the origins of life and organic matter in our universe.

Dr. Cyril Ponnamperuma, director of the Laboratory of Chemical Evolution at the university's College Park, Maryland campus, led a team of scientists who recently discovered amino acids — the basic building blocks of life — in meteorites found in the Antarctic. (See "Adaptable Life," AstroNews, December 1979.)

The laboratory examines lunar samples to find evidence of organic material, attempts to create molecules which may have existed in the Earth's or other planets' atmospheres prior to life, and examines pristine meteorite samples for evidence of organic matter.

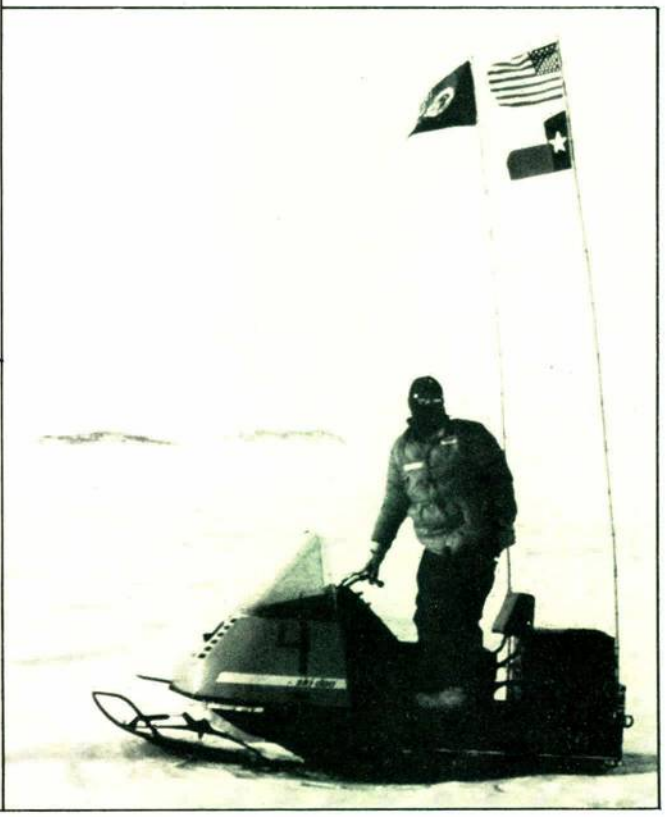
NASA supports this research in a variety of ways. The space agency had provided Ponnamperuma's team with samples of meteorites recovered from the Antarctic ice shelf, material brought from the Moon, and data on the atmospheres of other planets obtained by deep-space probes such as the Viking missions to Mars.

The Antarctic meteorite program was begun three years ago as a cooperative venture between the National Science Foundation and NASA. By collecting meteorites under extremely clean conditions, essentially identical to the manner in which Apollo astronauts collected lunar samples, joint NSF-NASA teams can provide scientists with samples so free of Earth contamination that they can be examined for evidence of an organic history before the time of their Earth impact.

Because the meteorites are protected from organic contamination while lying in the Antarctic ice and because the collection process prevents future organic contamination, Ponnamperuma considers them "the only prebiotic matter we have laid our hands on." The purpose, Ponnamperuma said, "is to find out whether in this meteorite, in this sample, there are any amino acids, any hydrocarbons."

Ponnamperuma's team had

*A NASA scientists sets out on a snowmobile for an Antarctic field trip on Rose Island in search of meteorites. NASA photograph.*



been very successful in this venture. The team has used gas chromatograph techniques to identify both right-handed and left-handed molecules of amino acids. The handedness refers to the direction to which a beam of polarized light would turn if shone through a solution of the dissolved material.

The Antarctic meteorites have provided strong evidence of both right and left-handed amino acids. Since all life forms on Earth contain only left-handed molecules, the pre-organic material found in the meteorites had to be formed somewhere else.

"The processes we postulated as taking place on the Earth before life began seem to have taken place somewhere else also," Ponnamperuma said. "What this implies is that all those events which led to life may be common in the universe, so what we said happened on the Earth may be happening somewhere else."

The meteorites which Ponnamperuma's team uses are about 4.5-billion years old. The oldest Earth material which has been identified is 3.75-billion years old and some of it shows evidence of organic matter. So far the program has produced as many meteorites in three years as had been collected in all years previous.

"I think the conditions are such that perhaps life exists only on Earth," he said, "but what about the billions of other solar systems. There's no question that there must be innumerable possibilities for life beyond the Earth."

In addition to the sample analysis program, the chemical evolution laboratory also works to reproduce the atmospheres of other planets.

Ponnamperuma is working with data provided by the Voyager Jupiter encounter to simulate that planet's outer atmosphere in a laboratory bottle.

"If we simulate a jovian atmosphere in our lab, we can come up with some of the colors we've seen on Jupiter, some of those reds and yellows. These colors are made by various molecules but can be synthesized in a jovian atmosphere," he reported.

The important aspect of this research, Ponnamperuma said, is that "if you have an atmosphere, if you have a source of energy — and we've seen pictures of lightning on Jupiter — organic molecules can be synthesized."

The laboratory also is proceeding with simulations of the saturnian atmosphere and that of the major moon of Saturn, Titan. These simulations are being conducted now in the hope of being able to compare results with that of the upcoming Voyager 1 Saturn encounter in November of this year.

Both the meteorite work and the planetary atmosphere synthesis experiments bear on the same questions — the origins of life.

"In the case of Jupiter, we are looking at reactions which are taking place right now. In the case of the meteorites we analyze, we are looking at what happened four-and-a-half-billion years ago when the gases of the primordial solar system gave rise to these molecules," Ponnamperuma said.

## The Elements in Old Stars

Using highly sensitive techniques, a team of astronomers at the University of Washington in Seattle has determined that the chemical composition of some of the oldest stars in the Milky Way Galaxy is considerably different than previously measured. Their finding, they said, should significantly affect theories that attempt to explain how the Milky Way was formed about 15 billion years ago.

The oldest stars in the Milky Way, the galaxy in which the solar system is located, are found in the globular star clusters. The stars in these clusters have been preserved in their original states for the last 15 billion years, and therefore provide a window to the physical and chemical makeup of the early galaxy and its origin.

Drs. Catherine Pilachowski, Ronald Canterna, and George Wallerstein examined the globular cluster 47 Tucanae, located about 25,000 light-years from Earth. In disagreement with earlier experiments, they found that 47 Tucanae contains concentrations of heavy elements such as iron, sodium, and calcium five times lower than had been predicted.

"For more than 20 years, 47 Tucanae has been considered the classic example of a metal-rich cluster, but it just isn't so," Dr. Wallerstein said. "We know," he added, "that during the evolution of the Milky Way, stars low in heavy elements formed first while those high in heavy elements formed later. This means that models describing the origin of the Milky Way, based on the assumption that globular clusters near the center of the galaxy must have been formed last because they are richest in heavy elements, will have to be seriously modified now that 47 Tucanae has been shown to be heavy element poor."

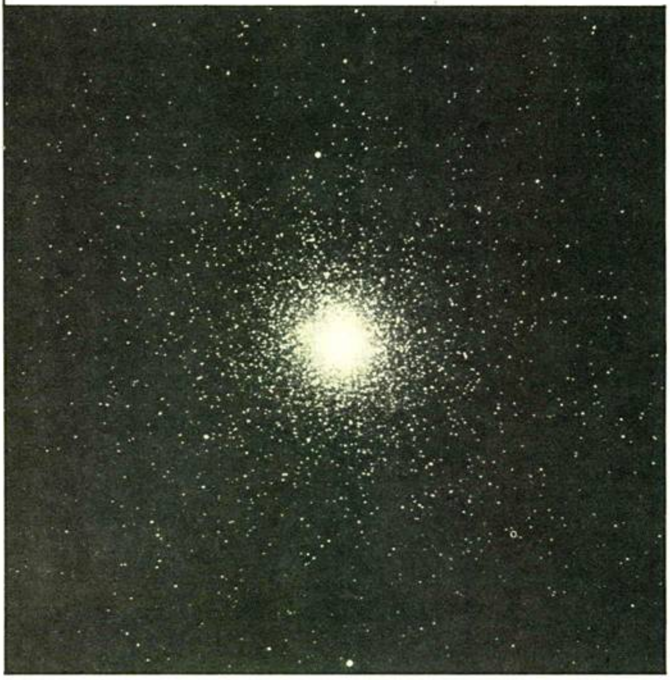
The study, funded by the National Science Foundation's Division of Astronomical Sciences and published in the *Astrophysical Journal*, demonstrates the power of sensitive experimental techniques over crude ones, Dr. Wallerstein said. Rather than viewing 47 Tucanae as a conglomerate of 100,000 neighboring stars to be studied by averaging their overall properties — as earlier workers have done — the astronomers limited their investigation to several stars in the cluster which they examined in extreme detail.

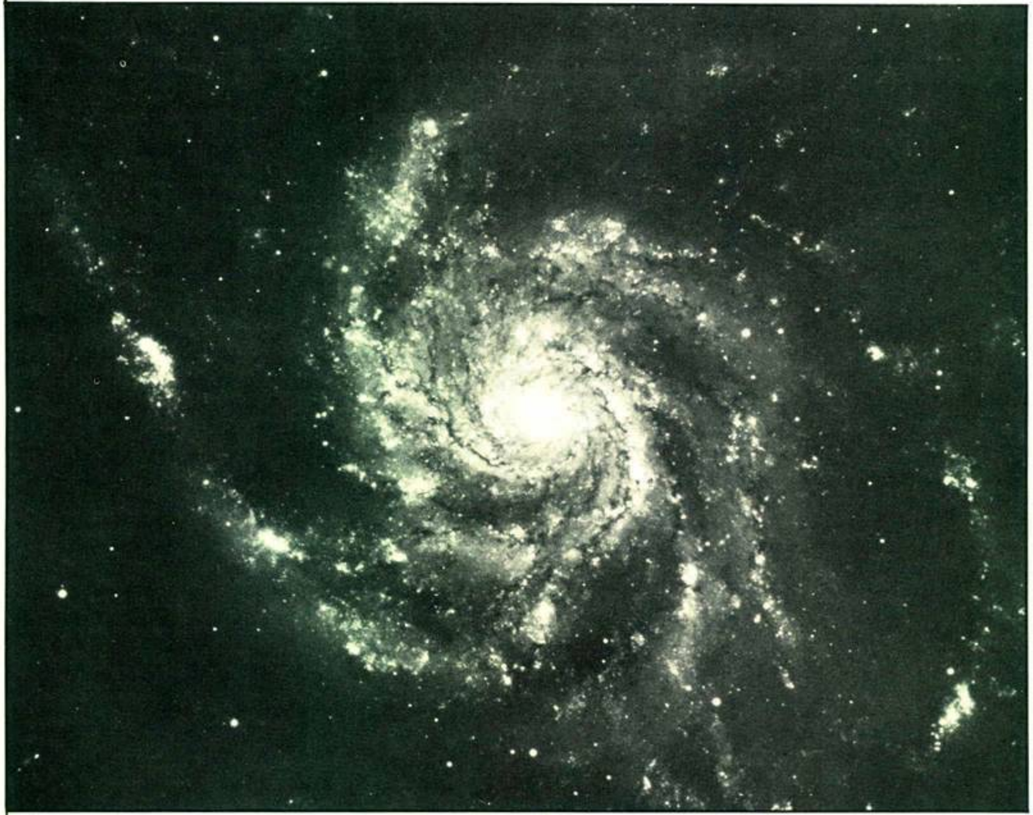
Since all the stars in any globular cluster were formed simultaneously under the same set of environmental conditions, their chemical compositions are "virtually identical," Dr. Wallerstein explained. It is, therefore, possible to learn about the whole cluster from just a few stars.

Dr. Wallerstein said a second study done independently and simultaneously at the California Institute of Technology in Pasadena has substantiated the University of Washington findings. By analyzing individual stars within M-71, another globular cluster long believed to be rich in heavy elements, Dr. Judith Cohen showed that, like 47 Tucanae, M-71 is poor in iron and other heavy elements.

Thus, Dr. Wallerstein said, both 47 Tucanae and M-71 are globular clusters that have been mistakenly classified because the methods initially used to study them were too imprecise. "It is becoming apparent that you have to analyze each globular cluster in much greater detail if you want to get it right," he said.

*Astronomers have discovered that old stars in the globular cluster 47 Tucanae are surprisingly low in heavy elements. Photo by Harvard College Observatory.*





*Individual stars recently observed in the spiral galaxy M-101 confirm the cosmological principle that physical laws are the same throughout the universe. Hale Observatories photograph.*

# The Physics of Distant Stars

The most distant stars ever observed outside the Milky Way and the Local Group of neighboring galaxies have been studied closely for the first time by an astronomer who reported that the stars' physical characteristics are like those of stars in our Milky Way. Her findings, she said, are strong evidence in support of an assumption long held by scientists that the laws of physics are the same throughout the universe.

Dr. Roberta M. Humphreys, professor of astronomy at the University of Minnesota, observed the very bright stars in the spiral galaxy M-101, 24 million light-years from Earth. She reported her findings to the National Science Foundation (NSF) which funded her research.

"These stars are the brightest yet observed in any galaxy, excluding stellar oddballs like supernovae (exploding stars)," Dr. Humphreys reported. "These extremely luminous stars are important to astronomers because they can be used as cosmic distance indicators. Stars like these may serve as beacons indicating the distances to more and more distant galaxies and will eventually yield a more accurate value of the Hubble constant, the rate of expansion of the universe."

The Minnesota astronomer also made observations of four stars in NGC-2403, another spiral galaxy about 12 million light-years away. All her observations were made with the 158-inch Mayall telescope at Kitt Peak National Observatory near Tucson, Arizona.

"Photographs reveal that these stars I observed are supergiants — the brightest, most massive stars known," Dr. Humphreys said. "They have luminosities more than a million times that of our own Sun and masses greater than 80 times the Sun's mass."

A few stars of comparable brightness, but none quite so bright, have been seen in our Galaxy and a few of its closest neighbors. Photographs also suggest that the temperatures and chemical composition of these supergiants are like those of similar stars in the Milky Way, Dr. Humpheys said.

The studies of such stars are important because they help confirm ideas about the formation and evolution of stars. Astronomers believe that the physical processes we observe occurring on the Earth, in our solar system and our Galaxy are basically the same throughout the entire observable universe.

"The spectra of these very distant stars in another galaxy show no significant differences from what we would expect, based on our knowledge of stars in the Milky Way," Dr. Humphreys reported to the NSF. "Although these very luminous stars literally represent only the tip of the iceberg of a total stellar population of hundreds of billions of stars in their own galaxy, we might suggest from this first look that star formation and evolution there are very much like what we observe in our Galaxy."

"It may be many decades before astronomers have comparable observations of the much fainter stars like our own Sun in such distant galaxies, but already we expect from these and other observations that they will also be similar to their galactic counterparts. It is not unlikely to expect that they would also have solar systems and perhaps even life."

Observations of these very distant and apparently very faint individual stars in other galaxies have become possible recently with the development of very fast spectrographs combined with light amplification systems on the largest telescopes such as the Mayall telescope at Kitt Peak.

# Hector *is* a Strange Asteroid

The Trojan asteroids are two groups of minor planets trapped by gravitational forces in the orbit of Jupiter, one group lying 60° ahead of the giant planet and the other following along 60° behind as seen from the Sun.

The brightest of these asteroids is 624 Hektor, and its brightness changes periodically by a factor of 3.1. This has been taken to imply either that Hektor has an enormous difference in albedo (degree of reflectivity) on opposite hemispheres, or that it is enormously elongated, possibly even consisting of two asteroids in contact, stuck together to resemble a giant peanut. (See "Hektor — A Strange Asteroid," ASTRONOMY, March 1979.)

Now new observations indicate that the second hypothesis, strange as it is, is in fact correct.

Writing in the February 29, 1980 issue of *Science*, William K. Hartmann and Dale P. Cruikshank point out that "a nagging problem...was lack of proof that Hektor is actually elongated," and therefore that its variation in brightness was not due to albedo differences. They were able to eliminate the second possibility by simultaneously observing the asteroid in both sunlight and thermal infrared.

If Hektor were truly spheroidal, the two light curves would be out of phase, with the maximum in reflected sunlight coinciding with a minimum in the infrared, since a more highly reflective surface would absorb (and radiate) less heat.

# AstroNews

Conversely, when the amount of reflected sunlight was at a minimum, the (darker) surface would be absorbing more light and the infrared emission would be at a maximum.

But if Hektor is in fact elongated, both light curves would be in phase, with the maxima and minima coinciding.

Observations made in April of 1979 at the Mauna Kea Observatory in Hawaii by the authors confirmed that the two light curves are indeed in phase, and therefore that Hektor is a highly elongated object. The researchers estimate its dimensions as 150 by 300 kilometers (93 by 187 miles).

Hartmann and Cruikshank point out that this does not in fact prove that Hektor consists of two formerly separate asteroids which have collided, but only that Hektor is not spheroidal. And they point out that Jupiter's innermost satellite Amalthea has been shown by Voyagers 1 and 2 to be an elongated object, measuring about 155 by 170 by 270 kilometers.

Still, further spectrophotometric observations could demonstrate a difference in composition in the two end views, which would be views of the two original objects. Such observations would confirm that Hektor is a composite asteroid, and one of the strangest in the solar system.

## Orbit and Climate

Periodic changes in Earth's orbit may cause long-term changes in the Earth's climate, including ice ages, according to new evidence. In studying the past two million years of the geologic record, Madeleine Briskin, associate professor of geology at the University of Cincinnati, found evidence of regular climatic variation preserved in deep sea sediments from both the Atlantic and Pacific Oceans. These variations, she said, correspond to cyclical changes in the Earth's motion through space and distance from the Sun.

Briskin's findings help to validate a theory first proposed in the 1930s by the Serbian meteorologist Milutin Milankovitch. He suggested that cycles in the Earth's motion cause climatic variation by affecting the amount of sunlight received by the Earth. The various cycles identified by Milankovitch and later researchers have periods of 23,000 years, 41,000 years, 93,000 years, and 413,000 years.

Other researchers have found evidence linking the three shorter cycles to climatic events, but previous evidence has been limited to much shorter periods of time, going back no further than 450,000 years. Briskin's results, based on the geologic record over the past two million years, constitute the first confirmation that the 413,000-year cycle also causes climatic changes. During the two longer cycles, the Earth's orbit around the Sun varies from nearly circular to somewhat elliptical.

"This motion from near circularity to ellipticity recurs in time with a regularity of 100,000 years, but maximum ellipticity is achieved every 413,000 years," Briskin said. "When the Earth is at a maximum distance from the Sun, the amount of solar energy received by the Earth is reduced by 28%."

In examining core samples from sea-floor sediments, Briskin found evidence that the Earth had passed through this cycle several times in the past two million years, and that the planet's climate had indeed been affected.

The two shorter astronomical cycles which help modulate climate include the timing of the seasons (precession of the equinox) and the varying tilt of the Earth's axis of rotation.

The timing of the seasons is changing because the Earth's axis, which now points to the star Polaris, is perpetually shifting direction in space and will, in 12,000 years, point to the star Vega. It takes over 23,000 years to complete one such cycle.

Obliquity, the tilt of the Earth's axis of rotation, changes from 23.5° to 21.5° relative to the Earth's orbital plane over a 41,000-year cycle.

The Earth's ice ages are conceivably triggered by the four cycles, Briskin said. She discovered changes in the composition of fossil plankton found in the deep sea core samples which indicate that the Earth experienced many ice ages. Briskin observed that these ice ages had varied in intensity and duration.

"For ice to form and accumulate in large quantities upon the continents, there must be a combination of falling upper-atmospheric temperatures and much rain or precipitation upon the continent," she said. "If low-pressure atmospheric systems were to release their moisture over an ocean, the Earth would experience cold phases without major changes in ice masses (such as glaciers) taking place."

Briskin said that astronomical changes force the atmosphere and ocean to adjust their circulation in a way which may trigger an ice age.

"Having identified the mechanism which causes the Earth's climate to change, we are now in a good position to anticipate future changes," she said.

This does not mean, however, that daily weather reports will soon include a countdown to the next ice age. The four astronomical cycles do not run in harmony with one another, nor are they as smooth as clockwork. Other factors — sunspots, for example — moderate the effect of these cycles. As Briskin puts it, there is "noise in the system."

Briskin said the Earth will oscillate between moderate cold periods or "mini-ice ages" and warm periods in the near future. We are now in the middle of a cooling period, she said, which should continue for thousands of years.

Eventually, as the Earth's orbit becomes more elliptical and the Earth's average distance from the Sun increases, we will "be on our way to a major ice age."

Briskin's research offers another breakthrough. Her evidence seems to indicate that the Earth's magnetic field experiences periodic changes which match the 413,000-year cycle. Scientists agree that the Earth's magnetic field is generated by activity in the Earth's core, but this had not been related to changes in Earth's orbit.

"I think this is extremely exciting," Briskin said. "This is a strong clue that there exists a link between orbital changes and the dynamics or churning of the Earth's core," although she added that this particular effect may not be a climate-related phenomenon.

## Jupiter's Weather

The two Voyager craft that swung by Jupiter last year collected over 30,000 photos of the moon system and the colorful banded atmosphere. To assess all of this information will take many years, and research groups all over the world are now getting on with the painstaking task of understanding this rich hoard of Jupiter pictures.

In England a group led by meteorologist Garry Hunt is interested in Jupiter's weather. Researchers at the image processing center of University College London aim to extract data on the behavior of atmospheric clouds from the Voyager pictures. From the Voyager data a clearer picture of cloud velocities has emerged. The light colored belts are a system of stable westerly winds. By contrast, the dark belts show unstable easterly flows. At the boundaries between these belts the gas flow is a chaotic swirl of storms. Turbulent eddies are made as the belts slide past each other at different speeds—they can be visualized as an endless succession of tornadoes.

For meteorologists the major finding is of waves in the atmosphere. Describing this result at a recent meeting of the Royal Astronomical Society in London, Garry Hunt said that clearly identifiable cloud structures found at regular intervals all around the planet are caused by "standing waves" in the atmosphere. But the Great Red Spot (GRS) is still a puzzle. The difference between it and the many white ovals spinning in the atmosphere is simply one of color. At least with the close similarity of the GRS to other features, scientists no longer have to explain it as a unique phenomenon.

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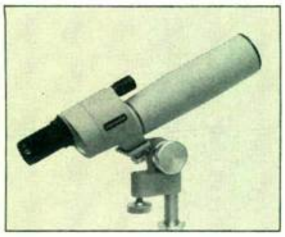

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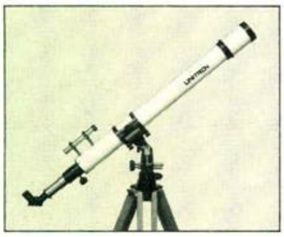

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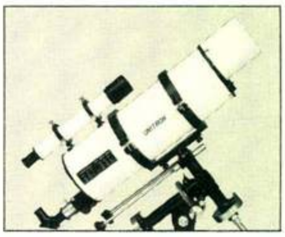

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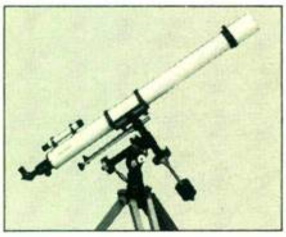

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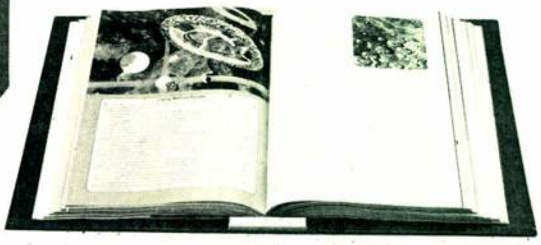

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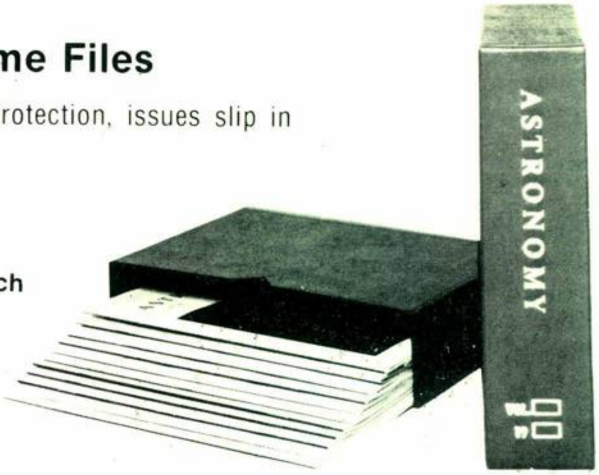

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# SUNSPOTS

by
Philip A. Stahl

Almost like animate entities, sunspots grow, divide — change. Day by day, week by week, month by month, they confound the observer with behavior that is not always well understood. Indeed, for over 400 years they have provided astronomers with a puzzle of the first order, defying any easy explanation of their origin and behavior.

Many questions about the Sun — and much interest in sunspots in particular — have once again been raised in this the year of solar maximum #21. What are sunspots? What causes them? And more fundamentally, what can they tell us about our own star? From solar physicists to shortwave hams, from climatologists to biologists, scientific attention is once again on the enigmatic islands of magnetism which we call *sunspots.*

Many people, including some astronomers who should know better, think that Galileo was the first to observe and record sunspots. But the observations, in fact, go back to ancient Chinese records of naked-eye sunspots. In order to be visible to the naked eye, a spot must be at least 25,000 miles across — an occurrence that's not particularly rare. In their records the Chinese refer to "flying birds" on the solar disk. These descriptions, however, undoubtedly refer to large groups of spots reaching or exceeding the naked limit of visibility.

Even considering Western culture alone, no one man can be given exclusive credit for discovering sunspots: they were actually discovered independently by Johann Fabricius, Father Scheiner-Cyrat, and Thomas Harriot, as well as by Galileo Galilei. Harriot was the first to observe them, while Fabricius was the first to publish and Scheiner-Cyrat second. The common belief that Galileo was the discoverer probably goes back to his rather presumptuous claim in his book *Il Saggiatore*:

> *"...it was granted to me alone to discover all*
> *the new phonomena in the sky and nobody else.*
> *This is the truth which neither malice nor envy*
> *can suppress."*

Galileo, however, must be credited with the most accurate early interpretation of their nature. In his published "Letters on Sunspots," Galileo convincingly demonstrated that the spots were not small planets circling the Sun (as Scheiner-Cyrat and others had assumed) but were phenomena on the surface of the Sun itself which shared its rotation. His personal theory was that the spots were:

> *"of the nature of vapours, or exhalations,*
> *of clouds or fumes."*

The famous English amateur, Sir William Herschel, also devoted much time to the study of sunspots in the early part of the 19th century. His own theory was that the spots were actually "holes" in the Sun's atmosphere, through which could be seen a dark surface — which he assumed to be inhabited.

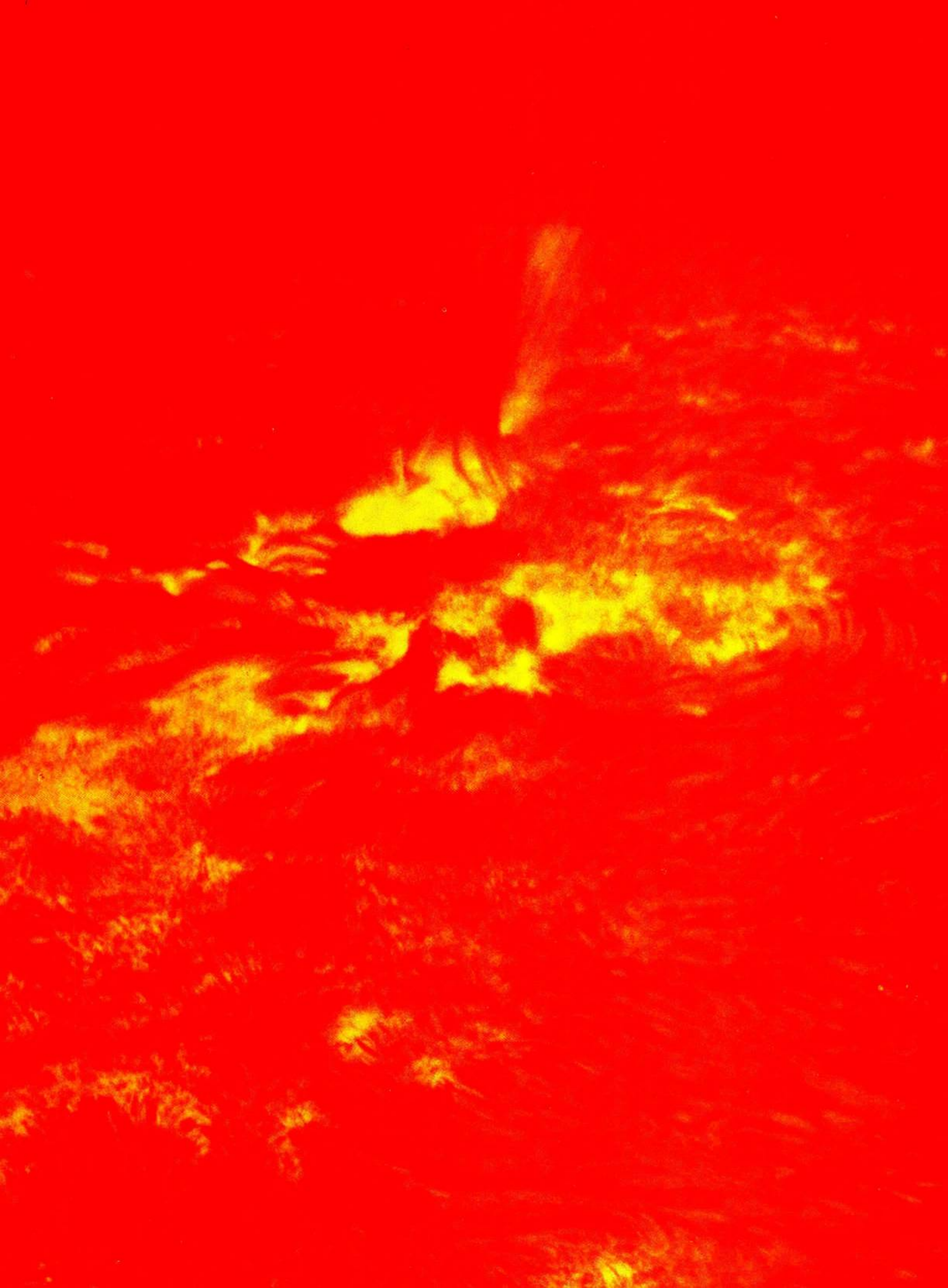
But our modern understanding of the sunspot phenomenon truly dates back to 1908, when George Ellery Hale discovered that sunspots possessed intense magnetic fields. How did he do this? From laboratory physics, we know that atoms in a magnetic field show unique effects in their spectra. The telltale combination of polarization and split spectral lines, called the *Zeeman effect,* signals the presence of a magnetic field. Hale knew this and found precisely that combination in sunspot spectra. When the patterns were shown to be the same as those obtained for the laboratory Zeeman effect, there could be no doubt that magnetic fields were associated with sunspots.

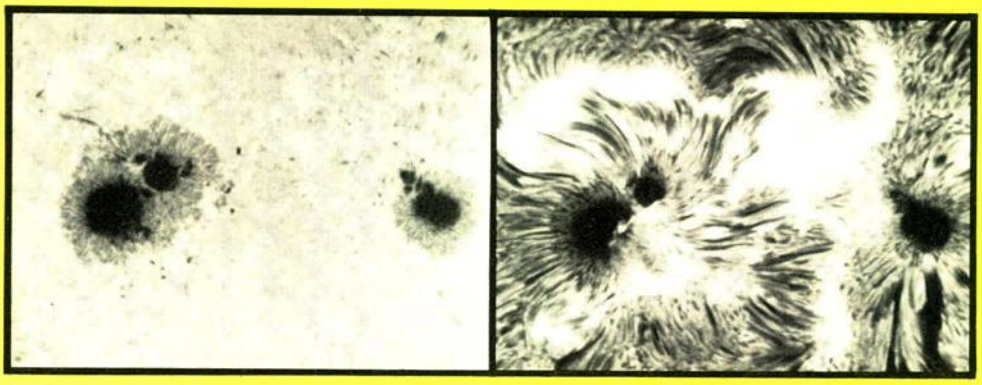
While Hale was perhaps the first to recognize the sunspot-magnetic field connection, his theory of sunspots was erroneous. Hale saw the spots as giant vortical storms, based on an incorrect analogy between terrestrial and solar atmospheres. (While pole to equator temperature differences would play a role in cyclonic disturbances on Earth, there are no significant pole to equator temperature differences on the Sun. The entire solar photosphere is essentially at the same effective temperature — about 5800° Kelvin.) Though the "storm" theory has now gone by the wayside — at least for solar physicists — it is still the predominant theory in the lay consciousness.

Most solar physicists today believe that sunspots have their origin in the solar convection zone. This zone can be thought of as a layer just below the photosphere — covering about 12% of the solar radius. In the convection zone, heat energy is transported to the photosphere by way of convection currents. Similar convection currents operate whenever you boil a saucepan of water. Water nearest the flame acquires an excess of heat energy first. It expands, rises, carrying with it the excess of heat energy to the mass of water above. As it surrenders the energy to its surroundings, its volume decreases, its density increases, and it sinks again toward the flame.

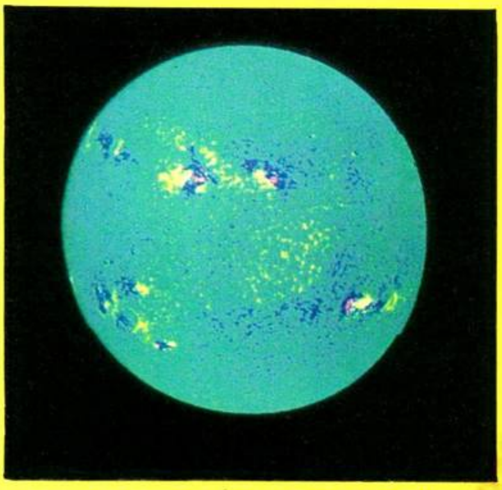
Solar granulation is the principal evidence of such a convection cycle in the Sun — thousands of "rice grain" structures occur at the level of the photosphere. It can be seen (provided you have good seeing) with a 6" or larger telescope.

**Sunspots resemble great swirling storms on the Sun's surface — but they're not. On close investigation, they turn out to be regions where intense magnetic fields have "locked in" the turbulent convection of solar gases. This picture, taken in the light of the red hydrogen spectral line, shows filaments of solar material aligned along the magnetic field around a sunspot. Sacramento Peak Observatory photograph.**

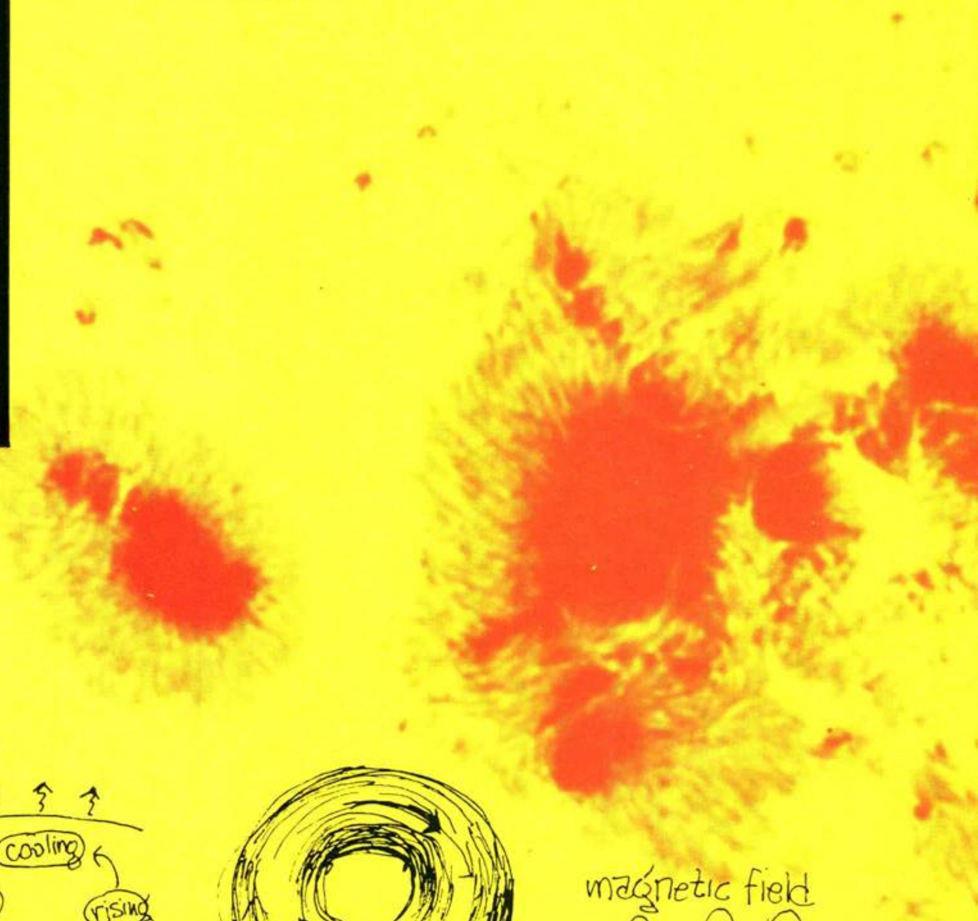




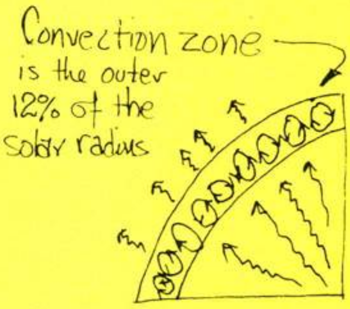
**The same sunspots appear dramatically different when studied with sophisticated modern solar telescopes. In white light, sunspots have a very dark umbra surrounded by a moderately dark penumbra. The surface of the Sun is covered with fine granulations. In hydrogen-alpha light, motions and temperatures show up as gray tones. Note the swirled appearance of the gases — much like iron filings around a magnet. Sacramento Peak Observatory photographs.**

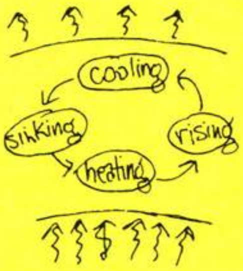


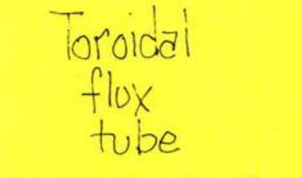
**Among the powerful tools of modern solar physics are images called magnetograms. The small colored regions are areas with magnetic fields. One color shows ( ) magnetic polarity, the other (-). Kitt Peak Observatory photograph, AURA, Inc.**

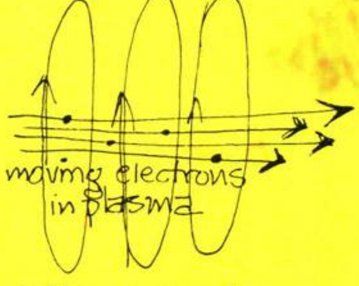


**Hale Observatories photograph.**









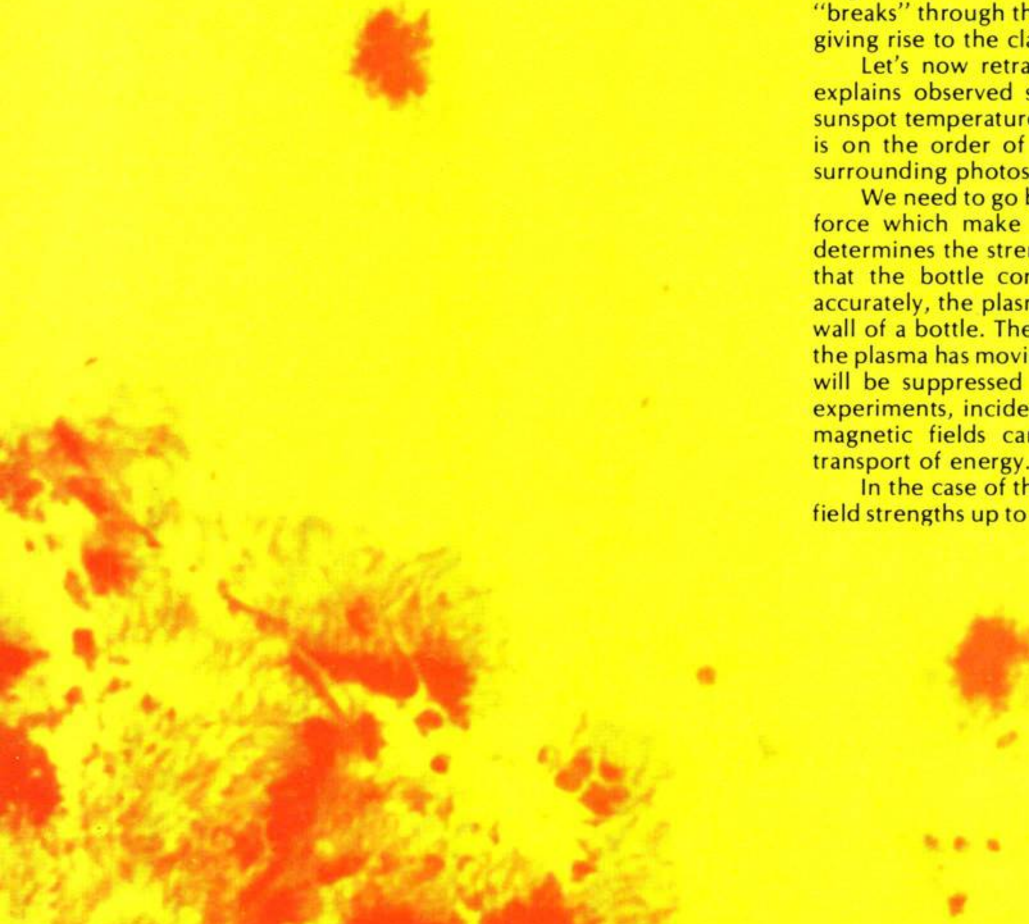
Now, let's examine this convecting fluid layer of the Sun a bit more carefully. It is hot — and many of the atoms in the fluid have lost one or more electrons. Imagine, if you will, a large number of stripped off electrons moving in concert within the convection zone. What can we expect? From physics, we know that moving electrons constitute an electric current — and also that an electric current gives rise to a magnetic field perpendicular to the current direction.

Let's go a step further: taken as a whole, the magnetic field contains lines of magnetic force, called *flux lines*, which you can think of as endless loops, closed on themselves, along which a compass needle would align itself. Together, the lines of magnetic force form what is called a *flux tube*.

A convenient way to think of a flux tube, which perhaps renders it a bit less abstract, is as a "magnetic bottle." The flux lines in such a "bottle" would serve an analogous function to the glass walls of the everyday bottle.

What does the magnetic bottle contain? We have a special name for the material: plasma. This is just a highly ionized gas with good conductive properties. The solar material in the convection zone, which is ionized, is a plasma.

That plasmas can be contained by magnetic fields in magnetic bottles has already been demonstrated. Indeed, this is the goal of physicists trying to develop atomic fusion power. Their experiments make use of devices called



*tokamaks,* in which a plasma is confined in a doughnut shape by an extremely strong magnetic field. The confinement times are currently only 1/10,000th of a second, though more efficient tokamaks, such as the Princeton Tokamak Fusion Test Reactor, are in the works.

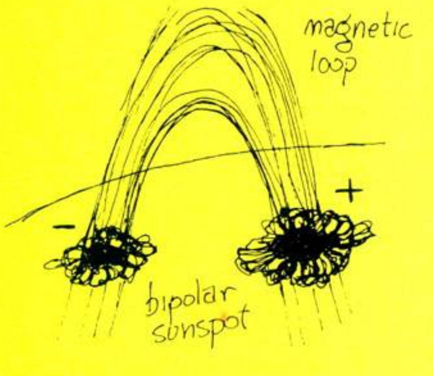
Solar physicists expect that in the solar convection zone, we may also find doughnut-shaped magnetic bottles, which, in the jargon of solar physics, are called *toroidal flux tubes.* These bottles are formed below the photosphere by electrons moving en masse in the solar convective cycle. The bottles may actually form rather deep down in the convection zone, but if conditions are right, they won't remain there.

Provided the strength of the vertical component of the magnetic field is great enough, the magnetic bottle — containing its plasma — will become buoyant and rise. By now you can probably guess what will happen if the magnetic bottle rises high enough. Right! The bottle "breaks" through the visible surface in two places (usually) giving rise to the classical bi-polar sunspot.

Let's now retrace our steps a bit and see how this explains observed spot features. From measurements of sunspot temperature, we know their effective temperature is on the order of 4000 K compared to 5800 K for the surrounding photosphere. Why are spots so much cooler?

We need to go back to the concept of lines of magnetic force which make up our bottle. The number of lines determines the strength of the magnetic field. Recall now that the bottle confines the plasma inside it, or more accurately, the plasma must do work to move through the wall of a bottle. The stronger the field, the more difficulty the plasma has moving, and the more efficiently convection will be suppressed within the plasma bottle. Laboratory experiments, incidentally, confirm that sufficiently strong magnetic fields can indeed inhibit convection — and transport of energy.

In the case of the Sun, the umbrae of sunspots possess field strengths up to 4000 gauss. This strong a field is capable of binding together neighboring masses of trapped plasma across magnetic lines of force. The convection cycle within the magnetic bottle is thereby inhibited, preventing new, hot rising elements from flowing horizontally and descending again. Convection is virtually shut off — so the temperature within the bottle must be less.

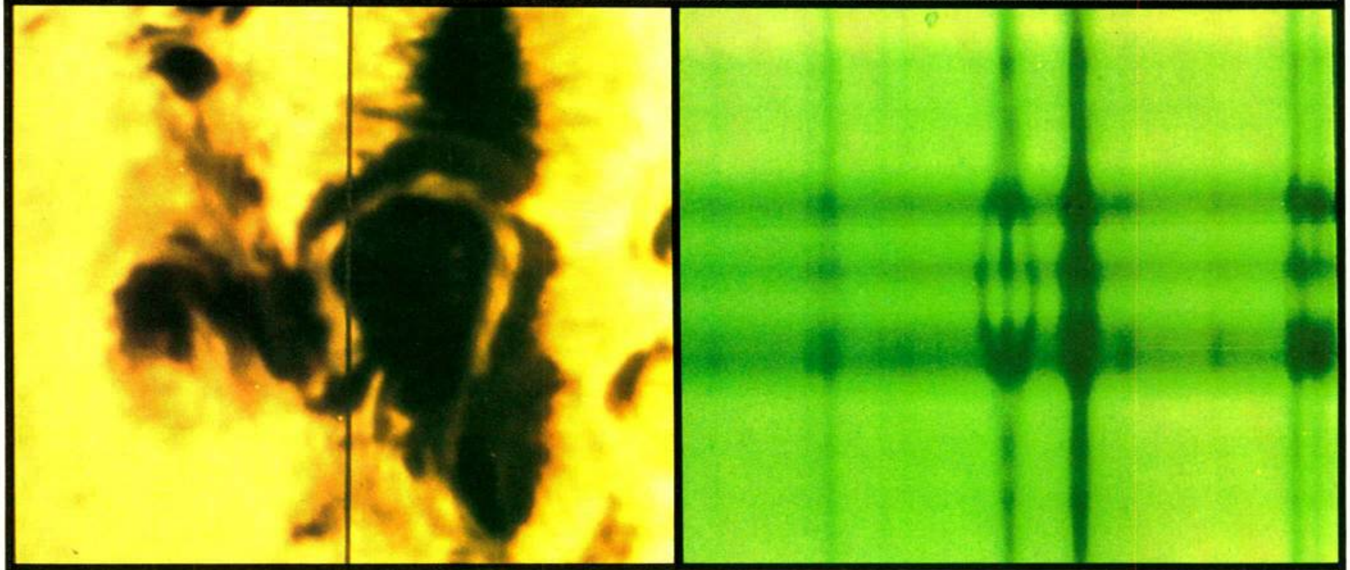


Not all the energy flow is shut off, however. One of the current raging questions of solar physics is just how much energy can still be transported within a confined solar plasma. Satisfactory theories must not only handle the complexities of convection, but must also take into account the relatively small amount of energy transported by radiation from the interior and absorbed by the plasma in a magnetic bottle. One problem, which we'll come back to, is that sunspots ought to have trouble staying as cool as they do.

Rather than being "storms" — the usual metaphor of popularized science — you've now seen that sunspots are actually relatively calm regions. In them, convection plays a minimal role and almost all energy transport is acccomplished by radiative transfer. This is especially true for the spot umbra, where the magnetic field is most intense. In fact, the darkness of a sunspot umbra is a good general indicator of the relative magnetic field strength. Usually the darker the umbra, the stronger the sunspot's magnetic field.

But what about the penumbrae, which appear to have a filamentlike structure? Think about what's happening at the umbral-penumbral boundary: it makes sense that the filaments are convective cells seen laterally. The magnetic field, "frozen" into the conducting plasma, causes the convective cells in the penumbrae to become arranged

## THE ZEEMAN EFFECT



There is perhaps no more graphic demonstration of sunspot magnetism than that afforded by the "splitting" of absorption lines in sunspot spectra. The photograph illustrates the effect, named after Peter Zeeman, the Dutch physicist who discovered it.

The patterns of Zeeman splitting vary from element to element but the line separation is always proportional to the magnetic field strength. More precisely, a magnetic field of strength B, in gauss, gives rise to a separation of wavelengths $[\Delta\lambda]$, such that

$$[\Delta\lambda] = (4.7 \times 10^{-5})\ [\lambda]^2\ B^2$$

where $[\lambda]$ is the normal wavelength position with magnetic field absent.

How does splitting of lines originate? A full, technically correct explanation involves rather detailed quantum mechanics, so we will confine ourselves to a crude example only.

Consider the hydrogen atom with its lone electron in circular orbit around the nucleus. Since a moving electron constitutes an electric current, and a current gives rise to a magnetic field, the atom acts like a tiny magnet. Now if we imagine the atom placed between the poles of an electromagnet, we see that electron's orbit will become oriented in a direction perpendicular to the lines of force.

To predict what happens to the atom, we'll now apply "Fleming's Left Hand Rule." Take your left hand and place the forefinger, second finger and thumb mutually at right angles. If your forefinger points in the direction of the magnetic field, and the second finger in the direction of the current, the thumb will point in the direction of the force.

For the case illustrated, the force is directed radially inward — toward the nucleus. However, this represents only one possible energy state for the electron. If we imagine the electron reversing its direction, then we arrive at another energy state. The application of the Left Hand Rule now indicates the force directed radially outward.

What does the presence of the magnetic field have to do with all this? The greater the field strength, the greater the difference in the electron's energy state between its clockwise and counterclockwise motions. The greater this energy difference, the greater the difference between the wavelengths of the Zeeman split spectral line.

Sunspots provide the best astronomical illlustration of the Zeeman effect, since it is relatively easy to home in on a large sunspot or group of sunspots. Also, the magnetic field strength is very high in sunspot regions — up to 4000 gauss in the umbrae of some spots. With the distant stars, other effects get in the way of precise study of spectral lines. We are truly fortunate to be able to study our own star's surface in such great detail.

along horizontal magnetic field lines. A simple analogy would be the way iron filings arrange themselves along the field lines of a bar magnet. By looking at the Sun in H-alpha, we see very similar patterns emerging around sunspots.

Let's think again about what's happening. Just outside the penumbrae, solar observers often detect relatively bright areas. They are called photospheric faculae if they're observed in white light, but most solar physicists group both photospheric and chromospheric faculae under the heading of *plages*. How do these bright areas arise? It makes sense that a suppression of convection within a sunspot region would be accompanied by a more efficient convection outside it. The more efficient convection outside the spot means more heat energy transported, so the surrounding gases become hotter and brighter. Sunspots then don't block the heat flow — they only redirect it around themselves.

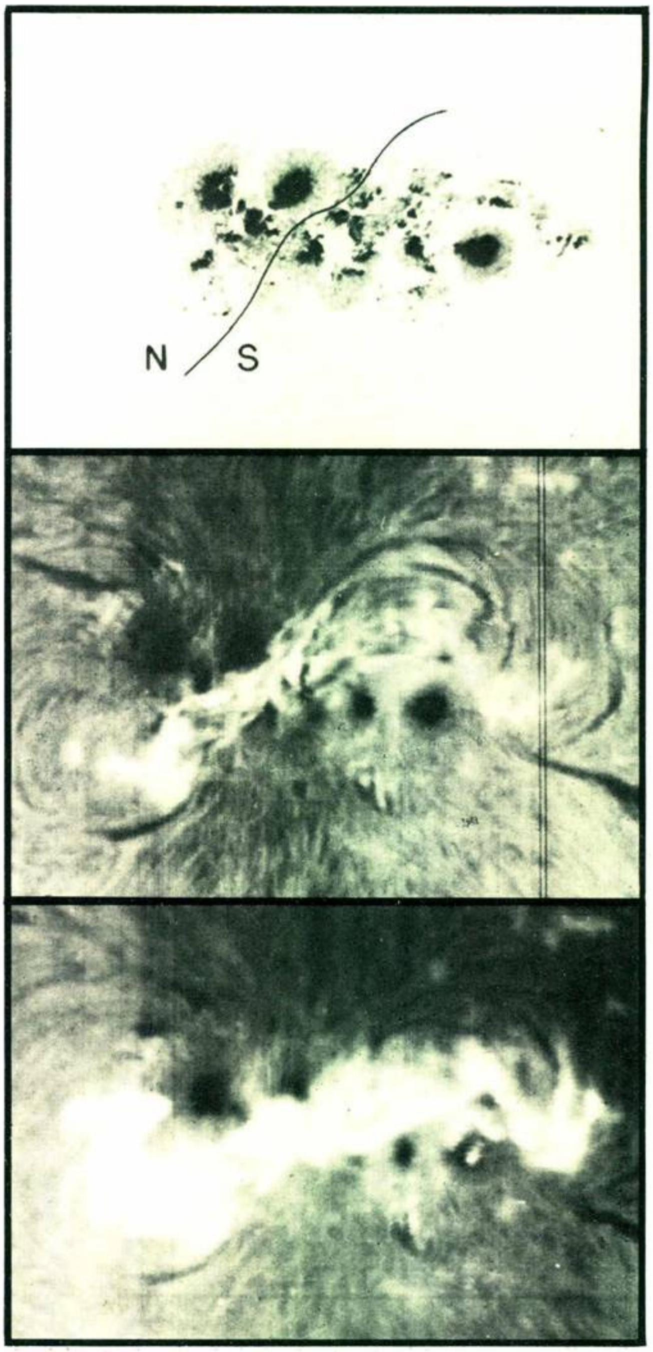
Note, however, that in most cases, increased brightening also precedes the eruption of a flux tube at the surface. Plages are the precursors of solar magnetic disturbances. Indeed, magnetograms (magnetic "pictures" of the Sun) reveal that plage areas have magnetic fields of 10 gauss — about ten times as strong as the general solar field.

Why then, you may be asking yourself, does increased magnetism in plage regions cause bright areas, but the even greater magnetism in sunspots result in dark areas?

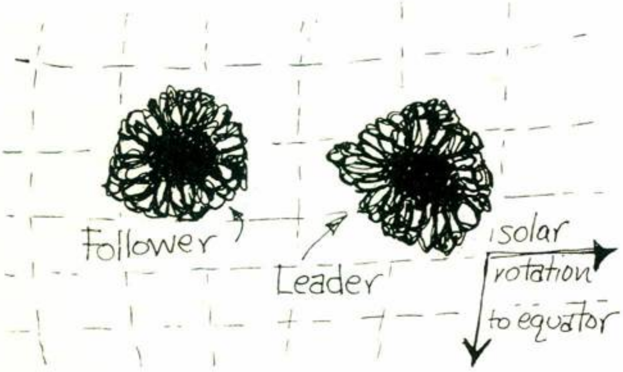
The reason, which you may already have pinpointed, is that the magnetic field of a typical plage is much less than the field associated with a sunspot umbra. The plage does not have sufficient magnetic strength to suppress, in any way, the transport of energy by convection.

By studying magnetograms, the solar astronomer can also determine the polarity (or direction of the magnetic field lines) in sunspots. Through the study of sunspot polarities, we realize that the sunspots in a group are not isolated from each other. Instead, they interact in complex ways.

For the simplest case, consider a typical bi-polar sunspot. It consists of two components of opposite polarity with a magnetic bottle bridging them — arching out of one



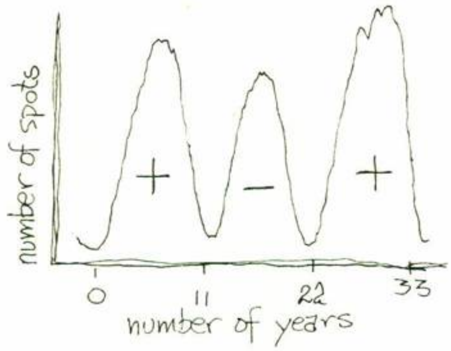
**Compare the white light photograph (top), marked to show the magnetic polarities of this complex sunspot group, with the hydrogen-alpha photograph (middle) which shows the alignment of the spot's magnetic fields. Shortly after the middle picture was taken, a solar flare occurred (bottom). Flares are sudden violent magnetic events that release huge amounts of energy and spew subatomic particles into space. Hale Observatories photographs.**



spot and into the other. For this simple case, we always give the individual spots the names "leader" and "follower." The leader always precedes the follower in rotation. It is also closer to the solar equator and, as a rule, is larger.

In the present solar cycle for the northern solar hemisphere, normal leader spots have "north" polarity, and followers "south." This is exactly reversed for the solar southern hemisphere. Most solar physicists prefer to designate sunspot polarities as (+) or (-) rather than north or south, to avoid confusion.

Sunspot polarities, by the way, provide the clue to the true solar cycle. Although spot numbers fluctuate in an 11 year cycle, the real cycle is a 22 year one since the polarity of sunspots is reversed after each 11 year cycle, and after 22 years, returns to the original polarity.



Though astronomers have learned much about the nature of sunspots, there are still many problems to be solved. For one thing, there is as yet no convincing theory to explain why and how some spots develop into major groups, while others don't. Also still unexplained is the nature of the force or forces which cause typical sunspots to assume a preferred tilt with respect to the solar equator.

But even more troublesome is how sunspots are able to persist at all — maintaining temperatures less than their surroundings. We can calculate, from the physicist's thermodynamics, that sunspots should gain heat gradually. Remember that, although convection is hindered, radiative heat transfer is still going on. Photons from the deep interior should be absorbed by the plasma magnetically bound in a flux tube. From the theory of radiative transfer, we know that a sufficiently large number of photons should be "thermalized" (i.e., their energy content converted to heat energy in the absorbing gas). Indeed, enough energy should be absorbed that a sunspot would reach equilibrium with the surrounding photosphere in three to five days. But sunspots last many months in some cases. How? We don't know.

One of the chief objectives for those of us participating in solar studies during this year of sunspot maximum is to seek answers to these and other perplexing problems. For solar astronomers involved in the great adventure of understanding our star, the reward lies in extending the frontiers of knowledge in a way which may well prove most useful to all mankind. As Dr. John Eddy has observed, "There is really only one thing that the world needs to know from astronomy — how does the Sun change?" That is the question for which we hope to provide a more satisfactory answer in this Solar Maximum Year.

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*Philip Stahl is a solar physicist at the University of the West Indies in Barbados. His research is directed toward a better understanding of the connection between sunspots and the tremendous eruptions known as solar flares. Other research interests include long period variable stars and X-ray binaries.*

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Coulter Optical . . . . . . . . . . . . . . . . . . . . 23
Criterion Instrument . . . . . . . . . . . . . . . . 87
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E&W Optical . . . . . . . . . . . . . . . . . . . . . . . 72
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Hansen Planetarium . . . . . . . . . . . . . . . . . 76
Harmony Of The Worlds . . . . . . . . . . . . . 73
Hirsch, Edwin . . . . . . . . . . . . . . . . . . . . . . 73
Hoosier Telescope Ctr. . . . . . . . . . . . . . . 74
Imagination Unltd. . . . . . . . . . . . . . . . . . . 72
Interstellar Enterprises . . . . . . . . . . . . . 74
L-5 Society . . . . . . . . . . . . . . . . . . . . . . . . 74
Little, Robert . . . . . . . . . . . . . . . . . . . . . . . 26
Luft, Herbert . . . . . . . . . . . . . . . . . . . . . . . 75
Main Camera . . . . . . . . . . . . . . . . . . . . . . . 76
Martin Enterprises . . . . . . . . . . . . . . . . . . 74
Meade Instruments . . . . . . . . . . . . . . . 44-45
Meyers, B.E. . . . . . . . . . . . . . . . . . . . . . . . 76
North Star Telescope Co. . . . . . . . . . . . . 73
Optica b/c . . . . . . . . . . . . . . . . . . . . . . . . . 77
Optical Techniques . . . . . . . . . . . . . . . . . 73
Optron Systems . . . . . . . . . . . . . . . . . . . . . 77
Pentax Corp. . . . . . . . . . . . . . . . . . . . . . . . 27
Questar Corp. . . . . . . . . . . . . . . . . . . . . . . 55
S&S Optika . . . . . . . . . . . . . . . . . . . . . . . . 29
Sky Scientific . . . . . . . . . . . . . . . . . . . . . . 74
StarTracker . . . . . . . . . . . . . . . . . . . . . . . . 37
Stellar Optics . . . . . . . . . . . . . . . . . . . . . . . 76
Texas Nautical Repair . . . . . . . . . . . . . . . 72
Tuthill, Roger . . . . . . . . . . . . . . . . . . . . . . 36
Venable, Thomas . . . . . . . . . . . . . . . . . . . 77
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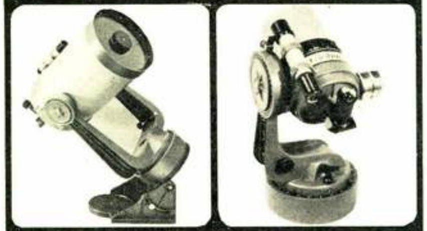

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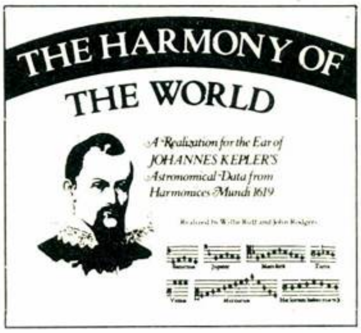
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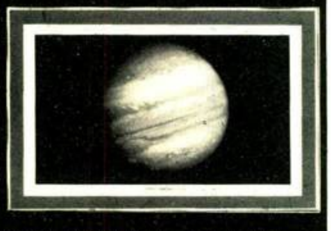

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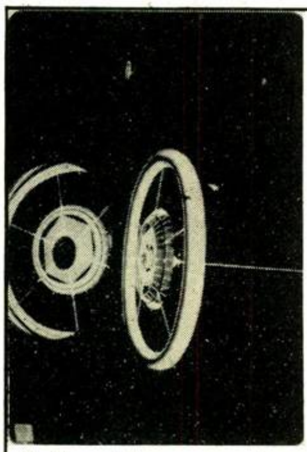

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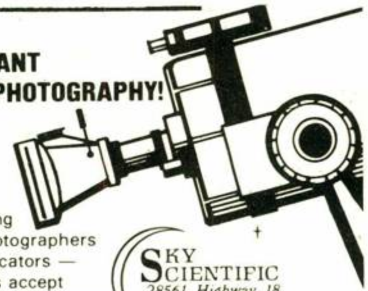

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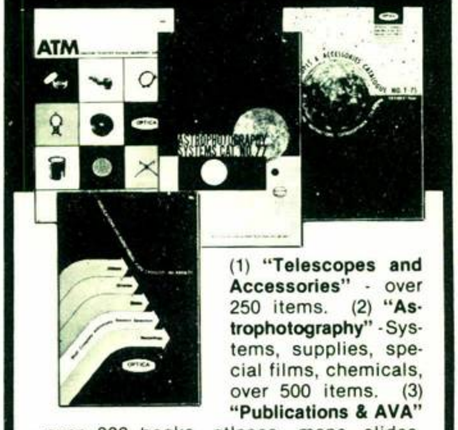

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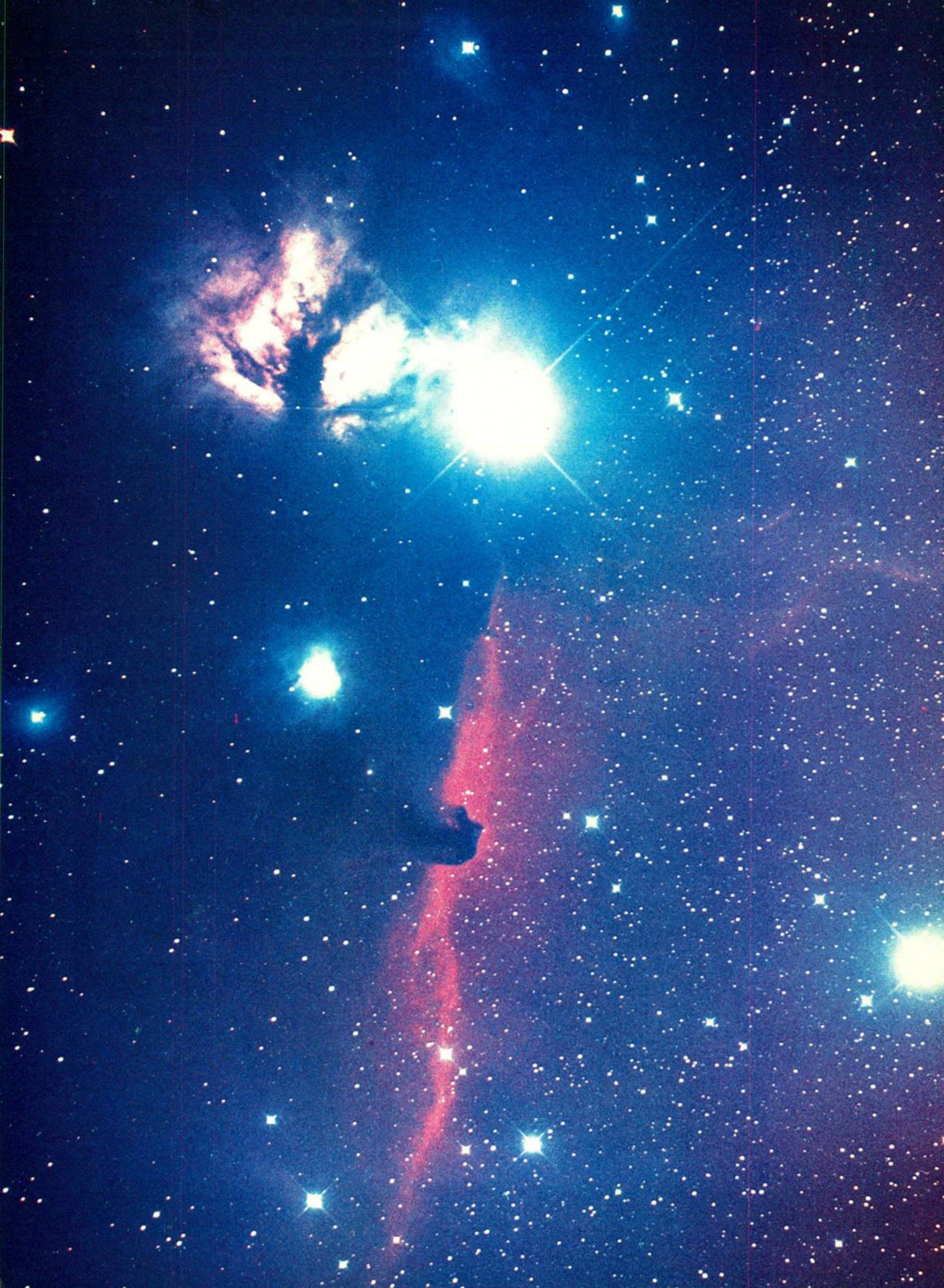


# close-up on virgo

## through the eyepiece

### Mercury

On the 13th of May, at 9$^h$ UT, Mercury will pass through superior conjunction into the evening sky. By late in the month, you might catch sight of it low in the west-northwest after sunset. Its brightness on the 26th will be -0.9 magnitude; by the 31st this will drop half a magnitude to -0.4.

The chance presence of Venus will make finding Mercury a lot easier: on the 25th, look for it about 10° below and 7° to the right of Venus. Day by day, Mercury will climb higher while Venus drops lower, seemingly to meet it. On the evening of June 1st, they'll be very close to each other, less than half a degree apart.

On May 24th, Mercury's 5.5 second of arc disk will be 86% lit — nearly "full" — as seen in a telescope; by the 31st it will grow to 6 arc-seconds and will be 69% lit.

### Venus

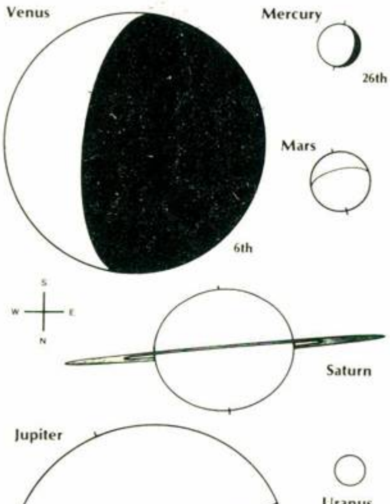
Every day during May, Venus will drop lower in the western evening sky as it heads for inferior conjunction on June 15th. On the evening of May 8th-9th, it'll be at maximum brightness (-4.2 magnitude).

Telescope owners will be treated to a fine view of Venus' crescent phases this month as the planet grows larger and its crescent thinner. By the middle of May, Venus will have surpassed Jupiter in apparent size, swelling from a diameter of 33 seconds of arc on the 1st to 52 arc-seconds on the 31st. During the same time, though, its disk will slim down from 34% lit to only 8%.

### Moon

There'll be an after-sunrise occultation of Aldebaran on the morning of the 15th, when a very slender crescent moon, just 26 hours old and only 4% lit, will pass through the Hyades. This will definitely not be an easy occultation to see, but good fun to try for.

The western part of North America won't see the event since the Moon will not have risen for them until the occultation is over. But observers in the east will see the Moon at elevations varying from only a few degrees (in the Midwest and South) to more than 25° (at Halifax).



Depending on where you're viewing from, the occultation happens between about 12:10 and 12:50 UT (this is 6:10 to 6:50 a.m. EDT). Generally speaking, the occultation comes earlier at southern sites.

If you're going to see this event, you need several circumstances on your side. First and most obvious, you need a clear day with no haze or clouds in the east. Second, you must find the Moon (which will be about 2° north and 1 hour of right ascension east of the Sun). Lastly, you have to find Aldebaran — a magnitude +1.1 dot somewhere to the east of the Moon's invisible dark limb. Here a red or orange filter will help immensely by darkening the blue of the sky. Get set up ahead of time; dashing out at the last minute won't achieve anything on this one.

### Mars

On the evening of May 2nd, the planets Mars and Jupiter together with the star Regulus (the brightest in Leo) will form a tight triangle 1.5 degrees across.

Two days later, Mars will pass less than a degree north of Jupiter, the last of the three conjunctions Mars has had with the giant planet since December.

Mars' brightness and apparent size have been dwindling steadily since opposition at the end of February: from its 13.8 seconds of arc diameter then, its size is down to 8.2 arc-seconds on the 15th of May. This is still within the range of enjoyable visual looking — especially if you've kept your eye in practice — but you won't have too many weeks longer to see much. Likewise, too, the brightness drops nearly a half magnitude during May — from +0.4 to +0.8.

These effects happen because over the course of May the distance between Earth and Mars will increase from 1.02 astronomical units to 1.27, an increase of some 37 million kilometers. The increase during May alone is nearly two-thirds of the entire distance at optimum (perihelic) oppositions!

Though Mars will be in the evening skies for a long time yet — it doesn't get caught by encroaching sunset until late in the year — it will soon be little more than an orange blob in your eyepiece.

**The Horse crooks its dusty Head in front of a glowing swath of gas, just south of Zeta Orionis. Jack Child used the 18" Newtonian reflector at Ford Observatory to make the three images for this tri-color photograph. This picture is the winner of the May "Best Astro-Photo" contest.**

### Asteroids

Of the four brightest asteroids (Ceres, Pallas, Juno, and Vesta) only 3 Juno is placed where it can be found and tracked easily. On May 15th, look for it at 8ʰ22ᵐ26ˢ, +14°26′10″ (1950 coordinates). It's a magnitude 9.5 object moving slowly eastward. But if you want to find it, don't dawdle: it sets around midnight, local daylight time.

1 Ceres is lost from sight in the Sun's glare, being at conjunction on the 18th.

2 Pallas, in Cetus, rises only a short while before the Sun does, but dedicated types can look for it on the 15th at 0ʰ48ᵐ42ˢ, +1°32′59″ (1950); it's at magnitude 9.8.

4 Vesta lies in Taurus at 4ʰ59ᵐ53ˢ, +20°59′28″ (1950 coordinates) on the 15th, but this part of the sky sets soon after the Sun does and you'll have difficulty finding this 8.3 magnitude object in the twilight.

### Jupiter

Close by Regulus and Mars in Leo, Jupiter this month forms a pretty grouping tailor-made for low-to-medium power scanning with your telescope. At midmonth, Jupiter will measure 38 seconds of arc across its equator and 35 over the poles; its brightness comes to -1.7 magnitude.

This month, a curious thing happens: Earth reaches greatest western elongation — from the viewpoint of someone at Jupiter! From May 21st to 25th, Earth will be nearly 11° west of the Sun, or to put it another way, as seen from the Earth, Jupiter will be at *quadrature*. Quadrature is a bit of astronomical jargon used to describe when a superior planet (one orbiting the Sun farther out than us) is 90° away from the Sun in the sky. At such times, superior planets show a slight gibbous phase: they don't have the perfectly symmetrical disks you see at opposition.

The shadowed part, called the *defect of illumination*, exists because at quadrature Earth lies off to one side of the planet relative to the Sun. Our line of sight is no longer virtually the same as a ray of light from the Sun — so we can peek around the side a little.

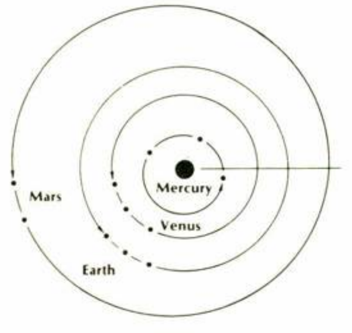
**Moon Data:**

| | |
|---|---|
| Last quarter | May 7 at 20:51 |
| New moon | May 14 at 12:00 |
| First quarter | May 21 at 19:16 |
| Full moon | May 29 at 21:28 |
| Last quarter | June 6 at 2:53 |
| Perigee: May 12 at 13ʰ | 362,198 km |
| Apogee: May 24 at 11ʰ | 404,832 km |

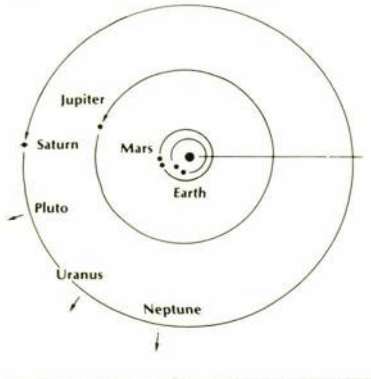
| Planet | Date | R.A. (1980.4) | Dec. | Mag. | Distance (AU) from Earth | Distance (AU) from Sun |
|---|---|---|---|---|---|---|
| **Mercury** | 10 | 2ʰ52.4ᵐ | 16°01.2′ | −1.7 | 1.32 | 0.32 |
| | 20 | 4ʰ20.2ᵐ | 22°42.1′ | −1.4 | 1.28 | 0.31 |
| | 30 | 5ʰ45.4ᵐ | 25°32.2′ | −0.5 | 1.12 | 0.35 |
| **Venus** | 10 | 5ʰ54.2ᵐ | 27°37.9′ | −4.2 | 0.45 | 0.72 |
| | 30 | 6ʰ09.1ᵐ | 25°45.3′ | −3.9 | 0.33 | 0.72 |
| **Mars** | 15 | 10ʰ23.7ᵐ | 11°48.1′ | +0.6 | 1.14 | 1.64 |
| **Jupiter** | 15 | 10ʰ13.0ᵐ | 12°18.9′ | −1.7 | 5.20 | 5.41 |
| **Saturn** | 15 | 11ʰ27.8ᵐ | 5°59.9′ | +1.1 | 8.97 | 9.46 |
| **Uranus** | 15 | 15ʰ24.9ᵐ | −18°22.8′ | 5.8 | 17.74 | 18.75 |
| **Neptune** | 15 | 17ʰ25.6ᵐ | −21°47.7′ | 7.6 | 29.38 | 30.28 |
| **Pluto** | 15 | 13ʰ37.1ᵐ | 8°50.9′ | 13.9 | 29.36 | 30.14 |

## Planet Finder

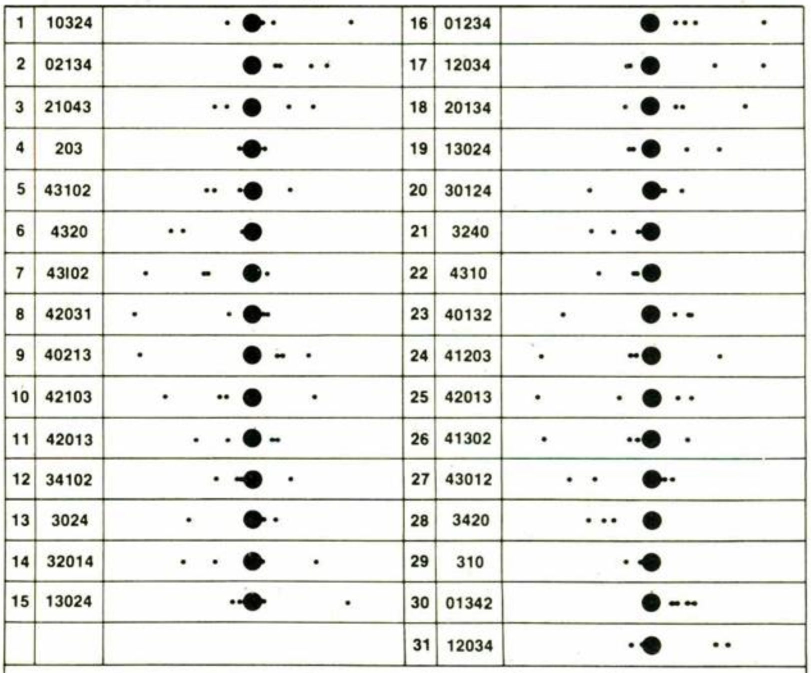
**Inner Solar System**



**Outer Solar System**



### satellites of jupiter 04:00 ut



| Day | Order | Day | Order |
|---|---|---|---|
| 1 | 10324 | 16 | 01234 |
| 2 | 02134 | 17 | 12034 |
| 3 | 21043 | 18 | 20134 |
| 4 | 203 | 19 | 13024 |
| 5 | 43102 | 20 | 30124 |
| 6 | 4320 | 21 | 3240 |
| 7 | 43102 | 22 | 4310 |
| 8 | 42031 | 23 | 40132 |
| 9 | 40213 | 24 | 41203 |
| 10 | 42103 | 25 | 42013 |
| 11 | 42013 | 26 | 41302 |
| 12 | 34102 | 27 | 43012 |
| 13 | 3024 | 28 | 3420 |
| 14 | 32014 | 29 | 310 |
| 15 | 13024 | 30 | 01342 |
| | | 31 | 12034 |

**Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4**
**(South is at top, matching the view in a telescope.)**

**Comet Bradfield had almost set behind the trees for Daniel Gooden of Chullora, NSW, Australia, when he took this 10 minute photo using a 135 mm lens and Ektachrome 400, the camera riding piggyback on an 8" telescope.**

The closer the planet orbits to us, the more obvious the effect: it's very noticeable with Mars, less so with Jupiter, and hard to find at all with Saturn. Uranus and Neptune look the same at all times.

With Jupiter the defect of illumination comes to only a third of a second of arc, but because the edge of the planet is darkened to start with (an effect of the jovian atmosphere), you should have no trouble seeing that the shape of Jupiter's eastern limb doesn't match the western one.

### Saturn

Saturn, the dimmest of the three planets in Leo at magnitude +1.1, spends the entire month to the southwest (lower right) of Denebola, the second magnitude star in the tail of Leo. Saturn is near the end of its retrograde loop, being stationary in right ascension on May 23rd.

Since it orbits the Sun nearly 10 astronomical units out, you see very little variation in its apparent size from month to month. At opposition, the ball of the planet averages about 19.5 seconds of arc in equatorial diameter; at conjunction, it's around 15.9 arcseconds — an 18% drop. (For comparison, Jupiter this year varies in size by 35% of its maximum diameter, Mars by 70%, Venus by 81%, and Mercury by 61%.)

Saturn thus lacks the exciting changes you see with some planets (Venus, for example). Instead, it gives your eye a chance to discern fine details through repeated observations. The oldest truth in observing is that the practiced eye sees more.

On the 17th of the month, the ring system will be tilted 1.6° to our line of sight, the maximum until late this summer. We have been looking at the southern side of the rings since March 13th and this will continue until July 23rd when Earth passes through the ring plane onto the northern side. When we do, it'll be the last we'll see of the rings' southern surface until 1994.

As the Sun during May is 1° to 2° north of the ring plane, the rings are backlit and very dark — quite invisible in small telescopes. Their full extent is over two times the equatorial diameter of Saturn — or about 42 seconds of arc — though it's unlikely you'll see their outermost parts except in a large instrument at a dark site.

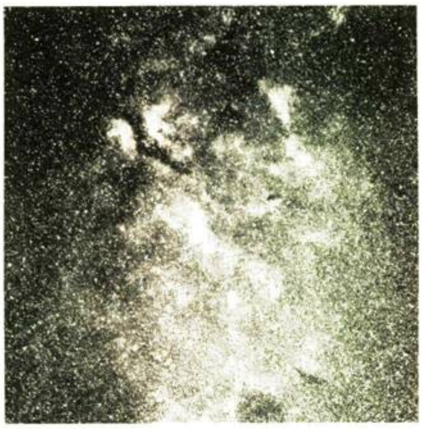
### Uranus

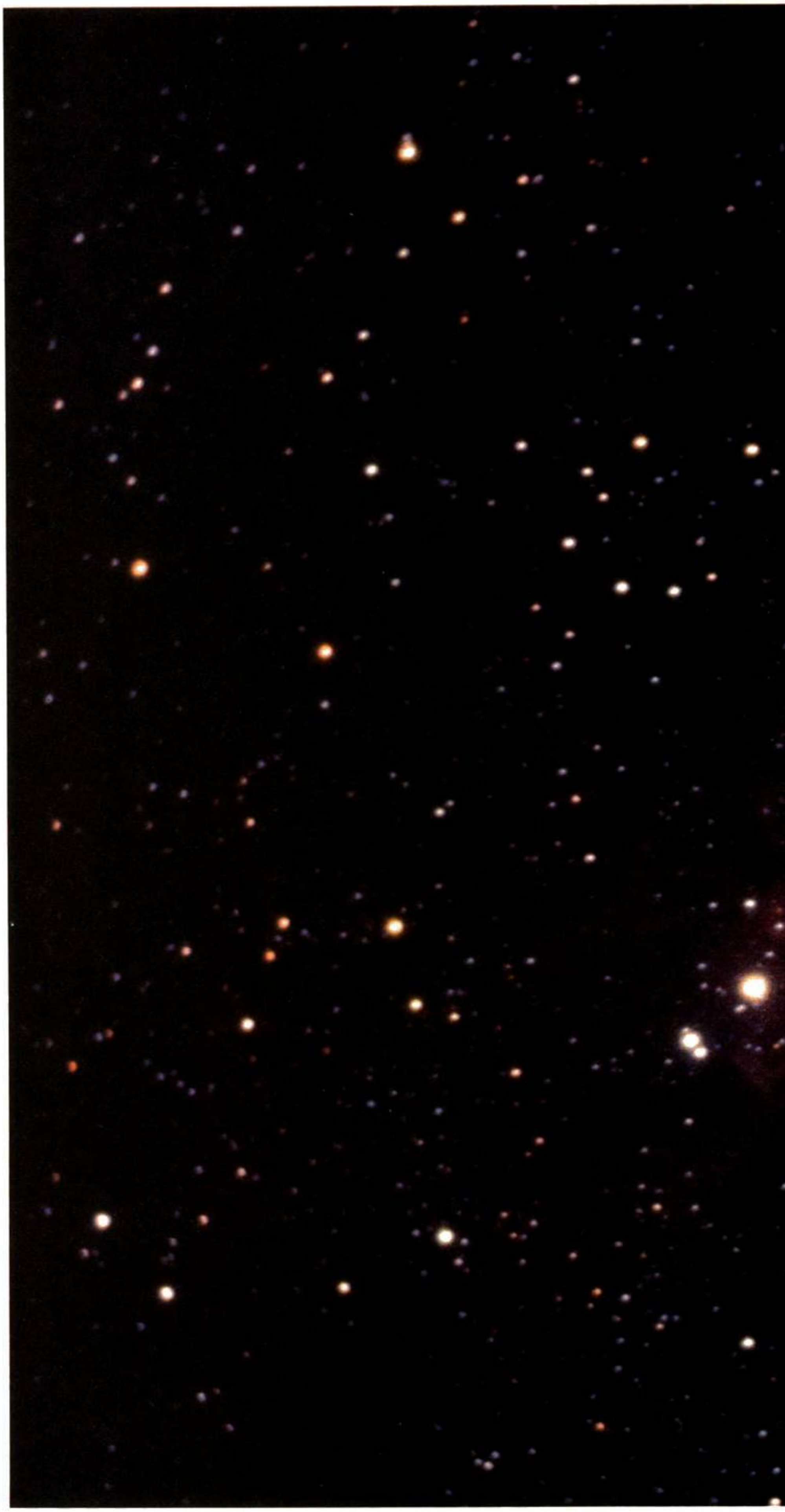
Uranus, being in Libra and at opposition on the 14th this month, will rise over the horizon murk to be seen clearly just about the time twilight ends.

It is now in the middle of its retrograde loop and will be found most easily by aiming your finder at Gamma ($\gamma$) Librae, the easternmost of the four stars marking the diamond-shaped asterism of Libra. Having centered Gamma in a low-power field of view, move your telescope southwest about 2°. Here you'll find a flat triangle of three stars (Zeta [$\zeta$], 34, & 32 Librae) extending 1.5° in an east-west direction; Uranus lies 2° farther to the southwest, and will have a grey-green disk (diameter: 3.9 seconds of arc; brightness: 5.8 magnitude).

Uranus' axis lies almost in the plane of its orbit — the axial tilt is 97° — and so twice each uranian year (i.e., once every 42 Earth years) we look alternately onto the planet's north and south poles. The north pole's turn comes in 1985, therefore we now have an almost straight-on view of Uranus' northern hemisphere.

You won't see any details, partly because you would need a huge instrument, and additionally because the polar regions of Uranus are pretty





**Above: Near Gamma Cygni, Lee Coombs shot a region rich in nebulosity and hot stars. Right: M-8, the Lagoon Nebula, offers fine views with almost any type of optical aid. Bill Iburg used a 5″ at f/5, chilled Ektachrome 400, and 40 mintues' exposure.**

featureless. Back when the planet was seen "side-on," however, observers with large instruments reported seeing cloud belts — as befits the gas giant it is.

Uranus has 5 known moons: Ariel, Umbriel, Titania, Oberon, and Miranda. All are dim and you'll need a big instrument to locate them positively. Miranda (mag. 17), Ariel (mag. 14), and Umbriel (mag. 17) are too close to Uranus (and/or too dim) to be seen in anything under a 24″, which leaves only Titania and Oberon as possibilities: both are at magnitude 13 to 14 and are the outermost uranian moons known.

Maximum separation from the planet for these moons comes when they are at greatest northern or southern elongation. Titania's elongation distance during May is about 34 seconds of arc, while Oberon lies farther out at 45.5″. Titania's orbital period is 8 days 17 hours, Oberon's 13 days 11 hours.

Titania will be at northern elongation on May 7th at 00:48 UT, May 15th at 17:54 UT, and May 24th at 11:00 UT. Oberon, having the longer orbital period, gets in only two northern elongations in May: on the 12th at 21:30 UT and the 26th at 9:00 UT. Southern elongations for both, of course, come half an orbital period earlier or later.

You'll need *at least* an 8″ scope or bigger and a dark sky. Remember that you're looking for two small, faint dots slowly circling Uranus in a counterclockwise direction — here you'll find nightly sketches and notes made at the eyepiece really handy.

### Neptune

Neptune, though fainter and smaller than Uranus, will be about as easy to find since it lies near a fourth magnitude star, Xi (ξ) Ophiuchi.

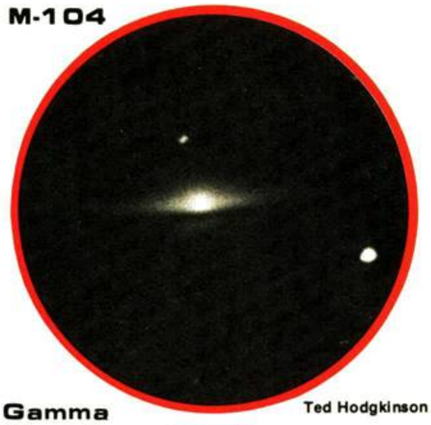
M-61

Bill Iburg

M-87

Thomas Dessert

M-104



Ted Hodgkinson

Gamma Virginis

James Mullaney

Center Xi in your eyepiece, then drop south about three-quarters of a degree. Neptune will be found just over 2° to the east, a tiny grey blob like Uranus, but with a disk only 2.5 seconds of arc in size and at magnitude 7.8.

### Meteors

Meteor aficionados are due for a probable disappointment with the Eta Aquarids this year since the shower maximum comes on the night of May 2nd to 3rd. The Moon, 3 days past full, will be lighting the skies until dawn.

Normally one of the better showers, the Eta Aquarids are fast, bright, and often leave long trails. Their radiant point, naturally, lies near their namesake star and rises around 2 a.m. local daylight time. You'd probably see 10 to 20 an hour on a moonless night, but reduce your expectations this time around.

## close-up on virgo

Virgo is the second largest of all the constellations (only elongated Hydra is bigger), but despite its huge size, most of its stars are dim. Only one, the brilliant white Spica, exceeds the third magnitude. Virgo is nevertheless well-stocked with exciting telescopic objects. Mention of Virgo immediately brings to mind the vast swarm of remote galaxies known as the Virgo-Coma (for Coma Berenices) Cluster. While only the brightest members of this cluster are listed in our table, literally thousands of galaxies have been identified as members of this enormous cosmic gathering.

**M-61**, an outlying member of the Virgo-Coma Cluster, lies somewhat south of the main concentration of galaxies. It is a fine face-on spiral of relatively large size, but at tenth magnitude, its surface brightness is rather low.

**M-84** and **M-86** are a pair of relatively small elliptical galaxies that make a fine sight in a single field of view. M-84, though slightly smaller, is brighter than its neighbor.

At a magnitude which varies from 12.2 to about 13, **3C 273** is the brightest of the quasars, and the best one for amateurs to seek out. For a finding chart, see "Observe a Quasar," ASTRONOMY, December 1979.

**M-49**, like M-61 an outlying member of the Virgo-Coma Cluster, is a fine, bright elliptical of estimated visual magnitude 8.6. Look to see if you can detect its slightly oval shape.

**M-87**, which lies at the center of this huge cluster of galaxies, is one of the largest galaxies known. It is also famous for the peculiar central jet which has been observed (in large observatory telescopes), but this won't be visible in your scope. Evidence seems to be growing that there is a giant black hole lurking at the center of this strange, energetic galaxy.

**M-101, an 8th magnitude galaxy in Ursa Major, is a beautiful spiral seen face-on. Lee Coombs used a 10" at f/5, 103a-O, and a 20 minute exposure.**

Close to M-87 are two other galaxies, one (**M-89**) an elliptical and the other (**M-90**) an edge-on spiral. Look for the distinctive spindle form of M-90.

**M-58** is a barred spiral galaxy seen nearly face-on. Larger apertures (10 inches and up) should reveal the outlines of the spiral arms emerging from the central bar.

Visually, **M-104** is the star of this month's region. Also known as the Sombrero Galaxy, it's a striking edge-on galaxy found in a relatively barren area. One of the brightest members of the cluster, the distinctive dark lane of dust should be visible in moderate-size (6 to 8 inches and up) instruments on nights of excellent seeing.

Known as Porrima, the splendid double star **Gamma ($\gamma$) Virginis** consists of perfectly matched 3.6 magnitude components four seconds of arc apart. The color of both is a white with a touch of yellow, lacking the color contrast of some other doubles, but a striking sight nevertheless.

**M-59** and **M-60**, a fine pair of elliptical galaxies, can be viewed at a relatively low magnification in the same field of view. M-60 will be about a magnitude brighter than its twin to the north.

The spiral galaxy **NGC-4699** is found only a few degrees from the Sombrero Nebula (M-104) to the southwest. Its relative isolation makes it stand out all the more, although no spiral structure will be visible.

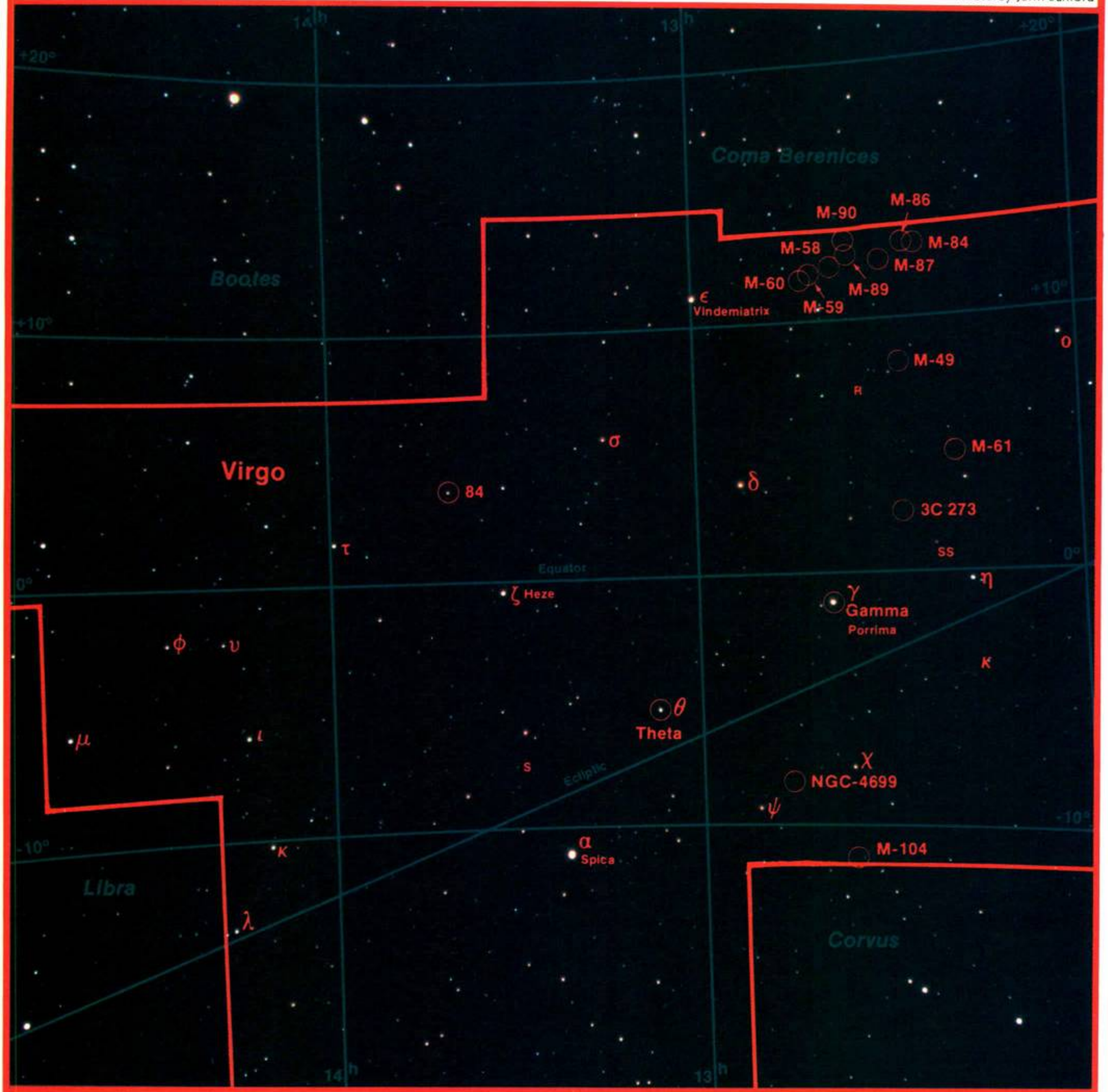
The triple system **Theta ($\theta$) Virginis** consists of a close (7") pair of stars at magnitudes 4.4 and 8.6, with a third, tenth magnitude component lying 71 arc-seconds distant at position angle 300°.

The pleasing double **84 Virginis** presents an orange and yellow contrast, with the two components separated by only 3 seconds of arc. Because of the magnitude contrast, the slight color contrast may be difficult to detect. Can you see it?

Map by Dewey Schwartzenburg

# virgo

Photo by John Sanford



14h
13h
+20°
+10°
0°
-10°
Coma Berenices
Bootes
Virgo
Libra
Corvus
Equator
Ecliptic
M-90
M-86
M-58
M-84
M-87
M-60
M-89
M-59
ε Vindemiatrix
M-49
o
R
σ
M-61
84
δ
3C 273
τ
SS
η
ζ Heze
γ Gamma Porrima
φ
υ
κ
θ Theta
μ
ι
S
χ
NGC-4699
ψ
α Spica
M-104
κ
λ

| Object | Type | Mag. | Size/Sep. Per. | R.A. (1950) | Dec. | R.A. (1980) | Dec. |
|---|---|---|---|---|---|---|---|
| M-61 | §S | 10.1 | 6′x5′ | $12^h19^m$ | +04°45′ | $12^h21^m$ | +04°35′ |
| M-84 | §0 | 9.3 | 2′ | $12^h23^m$ | +13°10′ | $12^h24^m$ | +13°00′ |
| M-86 | §0 | 9.7 | 3′x2′ | $12^h24^m$ | +13°13′ | $12^h25^m$ | +13°03′ |
| 3C 273 | quasar | 12.2-13.0 | irr. | $12^h28^m$ | +02°21′ | $12^h28^m$ | +02°11′ |
| M-49 | §0 | 8.6 | 4′x3′ | $12^h27^m$ | +08°16′ | $12^h29^m$ | +08°06′ |
| M-87 | §0 | 9.2 | 3′ | $12^h28^m$ | +12°40′ | $12^h30^m$ | +12°30′ |
| M-89 | §0 | 9.5 | 2′ | $12^h33^m$ | +12°50′ | $12^h35^m$ | +12°40′ |
| M-90 | §S | 10.0 | 8′x2′ | $12^h34^m$ | +13°26′ | $12^h36^m$ | +13°16′ |
| M-58 | §ʃ | 9.2 | 4′ | $12^h35^m$ | +12°05′ | $12^h37^m$ | +11°55′ |
| M-104 | §S | 8.7 | 6′x2′ | $12^h37^m$ | -11°21′ | $12^h39^m$ | -11°31′ |
| Gamma (γ) | ★$^2$ | 3.6,3.6 | 5″ | $12^h39^m$ | -01°11′ | $12^h41^m$ | -01°20′ |
| M-59 | §0 | 9.6 | 3′x2′ | $12^h40^m$ | +11°55′ | $12^h41^m$ | +11°45′ |
| M-60 | §0 | 8.9 | 2′ | $12^h41^m$ | +11°49′ | $12^h43^m$ | +11°39′ |
| NGC-4699 | §S | 9.3 | 3′x2′ | $12^h47^m$ | -08°24′ | $12^h48^m$ | -08°34′ |
| Theta (θ) | ★$^3$ | 4.4,8.6,10 | 7″,71″ | $13^h07^m$ | -05°16′ | $13^h09^m$ | -05°26′ |
| 84 | ★$^2$ | 5.7,8.6 | 3″ | $13^h41^m$ | +03°47′ | $13^h42^m$ | +03°38′ |

| | |
|---|---|
| ★ | *Star* |
| ★$^2$ | *Double Star* |
| ★$^3$ | *Triple Star* |
| m★ | *Regular Variable* |
| ∩★ | *Irregular Variable* |
| ℵ★ | *Eclipsing Variable* |
| ○ | *Open Cluster* |
| ● | *Globular Cluster* |
| ■ | *Planetary Nebula* |
| □ | *Bright Diffuse Nebula* |
| §0 | *Elliptical Galaxy* |
| §S | *Spiral Galaxy* |
| §ʃ | *Barred Spiral Galaxy* |
| §# | *Peculiar/Irregular Galaxy* |

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Every new Celestron we sell now includes our extension of Celestron's warranty; from one to two full years! And you can save hundreds of dollars with Orion's low prices!

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This handy new dewcap is as good looking as it is useful. It shields your optics from falling dew, minimizing 'fogging'. Made especially for Orion from the same high-strength tubing used by major telescope manufacturers. The beautiful baked enamel finish matches your C-8 perfectly. Slides in place in seconds, securing in existing accessory holes. A unique feature lets you use your counterweights while using our dewcap. **#5180—$29.95**

### Very Best Tripod Tray For Celestron 5 & 8

We've designed and built the finest all-aluminum accessory tray available. Easy to install, pops on & off in seconds. Stainless steel fasteners and oversized knobs give stability and security. One side has eleven 1¼" or .965" holes to fit eyepieces and accessories. Plenty of room for drive speed control. Alodine finish. 1¼" size (C-8), **#5721.** .965" size (C-5), **#5722. $39.95**

### Remote Power Inverter For Telescope Drive

Our AccuTrack 12 volt to 117 volt inverter, designed just for telescopes, is accurately regulated at 60.0 Hz to provide accurate drive speed. Very efficient operation, plugs in cigarette lighter or Porta-Pac. 10 watts, 10 ft. cord. **#2351—$39.95.**

### Porta-Pac Rechargeable Energy Cell

Away from home or car, the Porta-Pac gives you the power you need to operate your telescope drive all night on a single charge, when used with an AccuTrack inverter or Drive Speed Control. Small, lightweight (5 lbs.), spill-proof & maintenance free. Charger included. Cigarette lighter plug output. 12 volts, 5.0 amp-hours. **#2352—$49.95.**

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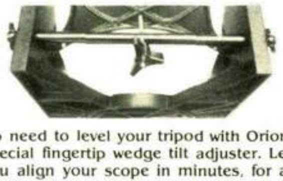
### Add Electric Declination Control To Your C-8

Our popular unit gives you the advantages of vibration-free electric declination, for error-free guiding, at a very moderate price. Designed specifically for astrophotography, matches the DriveSpeed Control right-ascension guiding speeds. Can be powered and controlled by a dual-axis AccuTrack OmniGuide unit such as the 3119 or 2119B, or by the accessory hand control with internal battery. It mounts in a few minutes, without drilling, using ordinary tools. Tucks under fork arm, doesn't interfere with storage. Power cable unplugs when not in use. Allows for manual dec. adjustments at any time. Model 3901 is for older C-8's with holes in fork arms. Model 3902 (illustrated) is for current model C-8's. **#3901—$39.95. #3902—$39.95.** Hand control with battery and cable. **#3909—$9.95.**

### Precision Polar Alignment Adjuster For Celestron 5 & 8



No need to level your tripod with Orion's special fingertip wedge tilt adjuster. Lets you align your scope in minutes, for accruate drive rate and setting circles. Solid steel components, black finish. **#5421—$24.95.**

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Locks on guide star and sends signals to your AccuTrack Deluxe or Digital Drive Speed Control. Makes guiding corrections automatically. Perfect for Celestron off-axis guider. The most popular star tracker in the world. **#2200—$124.95.**

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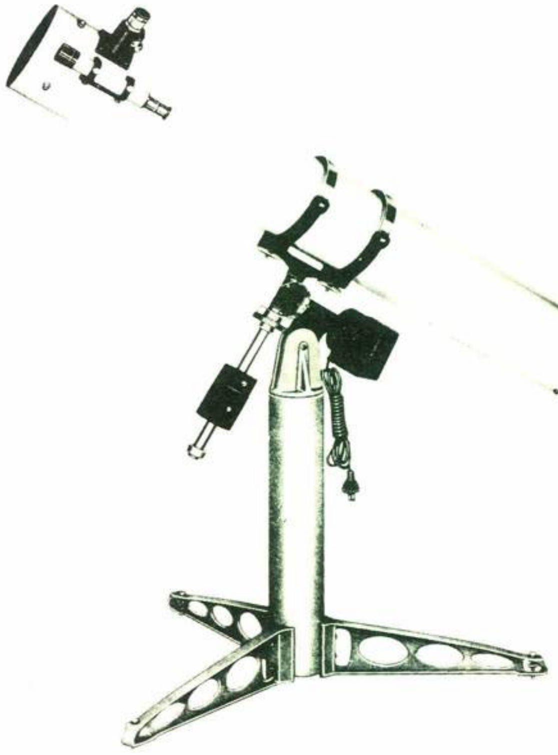

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**Celestron 8** Schmidt-Cassegrain Telescope

PRICE ANNOUNCEMENT

Effective June 1, 1980 the base price of the Celestron 8 will be increased from $995.00 to $1,150.00. Orders placed by May 31, 1980 will be accepted at the old price.

Great Orion Nebula Celestron 8 photo

Celestron 8

Send for free color brochure describing Celestron products, or send $2.00 for 32-page color catalog on how to select and use a Celestron. A comprehensive operating manual for the C8 will be sent for a $1.00 charge, upon request.

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